# Exhibit 3

# EXPERT REPORT
# OF
# PROFESSOR CRAIG PIRRONG

***Alaska Electrical Pension Fund v. Bank of America*,**
**Case No. 14-cv-7126 (JMF) (S.D.N.Y.)**

**HIGHLY CONFIDENTIAL**
**SUBJECT TO PROTECTIVE ORDER**

**July 28, 2017**

## Contents

# I. Introduction

1. Plaintiffs allege that the Dealer Defendants manipulated the various "ISDAfix" interest rates set by Defendant ICAP through various means. In particular, Plaintiffs allege that prior to 11:00AM on many days during the Class Period, the Dealer Defendants bought and sold (a) swaps on the ICAP interdealer trading venue and/or (b) Treasury securities traded on the BrokerTec electronic trading platform operated by ICAP in order to drive up or the ISDAfix rates that were based on the rates on these platforms at 11:00AM. Plaintiffs further allege that Defendants colluded and conspired in order to "rubber stamp" the Reference Rate circulated by ICAP in order to enhance the effectiveness of this "bang-the-fix" trading that occurred prior to 11:00AM.

2. The purpose of this trading and rubber stamping was to cause the ISDAfix rates to diverge from those that would have prevailed but for these activities, in order to increase Defendants' profits on positions (such as cash-settled swaptions) that had payoffs that were based on the ISDAfix rate.

3. Plaintiffs' counsel have asked me to analyze three issues.

4. First, whether there are accepted methodologies in the academic literature on "market microstructure" that can be applied in this case to implement formulaic approaches to determine the impact of Defendants' alleged manipulative activities on swap rates.

5. Second, whether there exist accepted methodologies in the market microstructure literature that can be applied in this case to implement formulaic approaches to quantify the damages caused by Defendants' alleged manipulative activities.

6. Third, whether the types of manipulation alleged by Plaintiffs would be likely to have persistent and cumulative effects on market swap rates, thus making class-wide analyses of impact and damages of multiple manipulative acts superior to more narrow analyses.

7. Based on my knowledge and expertise gained in twenty-seven years of researching market manipulation and market microstructure, and my analysis of data and other evidence produced in this case, I can answer all three questions affirmatively.

8. The academic market microstructure literature—which has had a substantial impact on financial market practices—has demonstrated theoretically that trades in a financial instrument (and offers to trade) should have transitory and permanent impacts on the price of that instrument. Furthermore, the academic market microstructure literature has developed, refined, and implemented a variety of empirical techniques to quantify the transitory and permanent impacts of trades and offers to trade on the prices of virtually every category of financial instrument, including stocks, bonds, currencies, and derivative instruments (of which the instruments at issue in this case are an example).

9. These well-known and widely used methods can be utilized in conjunction with available data in order to quantify in a formulaic way the impact of Defendants' allegedly manipulative trades on the ISDAfix rate specifically, and on swap rates throughout the Class Period. These methodologies can be applied in a formulaic way to the available data in order to determine the impact of manipulative acts for every major swap tenor on every day in the Class Period. Hereafter I refer to this quantified impact as the "artificiality ribbon."

10. Given an artificiality ribbon estimated using standard market microstructure methodologies, it is possible to quantify damages in a formulaic way. In brief, the prices and payoffs of all of the instruments at issue in this case vary in a formulaic way with swap rates: that is, these prices and payoffs are mathematical functions of swap rates. Using (a) data produced by Defendants on their transactions in various instruments, (b) standard formulae relating the prices and payoffs of these instruments to swap rates, and (c) the measured impact of Defendants' manipulative activities on rates, it is possible to determine in a formulaic way the damages suffered by the Class as a result of the Defendants' manipulative acts.

11. Finally, the standard theory of market microstructure implies that trades (and offers to trade) have permanent impacts on prices because (a) trades (and offers to trade) convey private information, and (b) information has permanent impacts on prices in an efficient market. Furthermore, the empirical market microstructure literature demonstrates that trades (and offers to trade) indeed have permanent impacts on prices in virtually all markets. Moreover, using these well-understood and often-applied empirical methods, it will be possible to quantify the permanent impacts of Defendants' manipulative acts in this case.

12. Since (a) the Defendants allegedly engaged in multiple manipulative acts on different days during the Class Period, and (b) these manipulative acts likely caused permanent impacts on swap rates, the impact of the Defendants' alleged manipulative acts cumulated over time. Due to this cumulative effect on multiple instruments traded by the myriad members of the Class over the entire Class Period, class-wide analyses of impact and damages are superior to more narrow analyses limited to single acts by

individual Defendants. That is, the nature of the allegations necessitates an analysis of the collective and cumulative impact on numerous individuals of the Defendants' actions.

13. The remainder of this report is organized as follows. Section II lays out my background and qualifications. Section III reviews Plaintiffs' allegations. Section IV draws upon market microstructure research to explain how trades impact prices, and these prices impacts can be exploited to manipulate markets and thereby cause prices to diverge from those that would obtain in a competitive, unmanipulated market. Section V presents a methodology developed in the market microstructure literature that can be used to quantify the impact of Defendants' manipulative acts in a formulaic way, resulting in the creation of the "artificiality ribbon." Section VI illustrates how that ribbon can be used to determine, in a formulaic way, the effect artificiality had on the type of financial instruments entered into by Class Members here. Section VII discusses how this can be "scaled up" to calculate damages for individual Class Members, damages arising out of only one Defendant's transactions, or for the entire Class. Section VIII again puts this all into practice, for instance applying the artificiality ribbon discussed herein to the named Plaintiffs' data to determine whether they were negatively impacted, and to a portion of Defendants' data to assess how other Class Members fare under it. Finally, Section IX demonstrates that "rubber stamping" greatly enhanced the effect of "bang-the-fix" manipulative trades, and would not have occurred absent a conspiracy among the Defendants.

## II. Background and Qualifications

14. I am Professor of Finance, and Director of the Global Energy Management Institute at the Bauer College of Business of the University of Houston. Prior to joining the

faculty of the University of Houston in January, 2003, I was the Watson Family Professor of Commodity and Financial Risk Management at Oklahoma State University. I assumed this endowed professorship in 2001 after holding research and teaching positions at the University of Michigan, the University of Chicago, and Washington University. My *curriculum vitae* is attached as Appendix 1. It lists all of the publications that I have authored in the last ten years. It also lists cases in which I have testified as an expert at trial or by deposition within the preceding four years.

15. I have researched the economics of financial, futures, and securities markets for most of my academic career. I have published scholarly articles concerning financial, securities, and futures markets. I have written articles on the behavior of derivatives prices, the organization and governance of futures exchanges, and various aspects of futures market regulation, including the regulation of market manipulation.

16. As an academic and consultant, I have been deeply involved for about 25 years in issues relating to derivatives markets, derivatives prices, and the economics of derivatives market manipulation. My research has been published in a wide variety of scholarly journals. I have been a peer reviewer for many journals, including the American Economic Review, the Journal of Finance, the Journal of Law and Economics, the Journal of Futures Markets, Economic Inquiry, the Journal of Economic Behavior and Organization, the Journal of Business, and the Journal of Business and Economics Statistics.

17. Much of my research has focused specifically on issues of market manipulation. I have published a book (titled *The Economics, Law, and Public Policy of Market Power Manipulation*), as well as eleven economics, finance, and law review articles

on this subject. My survey article on the economics of manipulation was recently published in the *Journal of Commodity Markets*.

18. In 1992 I was a member of the MidAmerica Institute for Public Policy Research Treasury Securities Market Task Force. This Task Force was formed in the aftermath of the Salomon Brothers squeeze of the two year Treasury note. As a member of the Task Force, I investigated issues relating to microstructure and market power in the market for Treasury Notes and Bonds.

19. I have consulted with commodity exchanges in Sweden and Germany regarding the design of futures contracts, including the design of the delivery mechanisms for wood pulp, European wheat and European pigs. A main objective was to design contracts that were not vulnerable to manipulation.

20. In 1997 and 1998 I served as a member of the CBOT's Grain Delivery Task Force ("GDTF"). This body was charged by the exchange with the responsibility of designing new delivery terms for CBOT corn and soybean futures contracts. Such a redesign was mandated by the United States Commodity Trading Futures Commission ("CFTC") because the old delivery mechanism had become unduly susceptible to manipulation due to a decline in deliverable supply caused by the closure of several delivery warehouses in Chicago. Among the Task Force's objectives was to design a contract that would tend to prevent and diminish the likelihood of price manipulation. Estimation of deliverable supply, as defined by the CFTC, for alternative contract designs was one of the Task Force's main responsibilities, and I performed most of the work on this subject. The terms recommended by the GDTF were adopted by a large majority of the CBOT

membership, and approved by the CFTC (with some modifications for soybeans) in May, 1998.

21. In 1994 I was retained by the Winnipeg Commodity Exchange to evaluate the performance of its canola futures contract in the aftermath of a suspected manipulation, and to make recommendations on the redesign of the contract. The exchange ultimately adopted these recommendations.

22. The Winnipeg Commodity Exchange also retained me to investigate and to provide expert testimony in a disciplinary action against the suspected manipulator.

23. In June 2005, I was retained by FERC to make a one-day presentation on the economics, law, and regulation of market manipulation to economists, analysts, and attorneys in the agency's Office of Market Oversight and Investigation. I made this presentation in June 2005.

24. I have testified before the House Agriculture Committee (which has jurisdiction over futures markets and exchanges) on matters relating to market manipulation.

25. I was an invited participant in the Federal Trade Commission's workshop on its proposed oil market manipulation rule.

26. I have taught courses on derivatives (including futures, options, and swaps) at the graduate and undergraduate levels for twenty-eight years. These courses have covered the pricing of derivatives instruments, including natural interest rate derivatives, the use of derivatives for hedging and speculative purposes, and manipulation. I currently teach the PhD course in futures and options in the Bauer College of Business at the University of Houston, and an MBA course in energy derivatives. The PhD course covers interest rate derivatives, including interest rate swaps, swaptions and exotic derivatives, in great detail.

27. I am currently director of the Global Energy Management Institute ("GEMI") at the Bauer College of Business of the University of Houston. GEMI is a world leader in energy finance education. Moreover, GEMI routinely hosts educational events for energy professionals, including a well-attended energy trading conference held every year.

28. My research has been cited in a 7th Circuit Court of Appeals decision on manipulation. Board of Trade v. SEC, 187 F.3d 713, 724 (7th Cir. 1999) (Easterbrook, J.).

29. The CFTC retained me as an economic expert in a commodity manipulation case. I have also served as an expert in manipulation matters by the Winnipeg Commodity Exchange, pursuant to enforcement actions undertaken by the WCE. I have provided expert testimony in various cases related to market manipulation. These include *In re* Soybean Futures Litigation, Nos. 89 C 7009, 90 C 1138 (N.D. Ill. 1995), American Agric. Movement v. Board of Trade, 848 F. Supp. 814 (N.D. Ill. 1994), *aff'd in part*, *rev'd in part sub nom*. Sanner v. Board of Trade, 62 F.3d 918 (7th Cir. 1995), Kohen v. Pac. Inv. Mgmt. Co., 2007 U.S. Dist. LEXIS 56389 (N.D. Ill. 2007), Energy Transfer Partners, L.P (FERC Docket No. IN06-3-003), Puget Sound Energy, Inc. v. All Jurisdictional Sellers of Electricity et al (FERC Docket No. EL01-10-085), San Diego Gas & Electric Company v. Sellers of Energy and Ancillary Services Into Markets Operated by the California Independent System Operator Corporation and the California Power Exchange (FERC Docket No. EL00-95-248), and Public Utilities Commission of the State of California v. Sellers of Long-term Contracts to the California Department of Water Resources et al (FERC Docket No. EL-02-007).

30. I am being compensated at a rate of $900 per hour for my work in this litigation, and was assisted by a team working under my direction and control at Compass

Lexecon. My compensation is in no way contingent upon my opinions or the outcome in this matter. A list of the materials that I relied upon in the preparation of this report is attached as Appendix 2.

## III. Allegations

31. Plaintiffs allege that Defendants manipulated the USD ISDAfix through trading activities. Specifically, Defendants timed their trading activity to align with the ISDAfix setting window in order to move the Reference Rate. This was analogous to "banging the close" or "banging the settlement" on futures markets or stock markets. I will therefore refer to it as "banging the fix."

32. Plaintiffs allege that this trading occurred at various times over three different trading venues: the ICAP interdealer swaps brokerage platform, the BrokerTec electronic trading platform for US Treasury notes and bonds, and the Eurodollar futures contract on the Chicago Mercantile Exchange.[1] Plaintiffs allege that manipulative trading on ICAP affected the ISDAfix because the ISDAfix rate was determined on the basis of the sum of the swap spread over Treasuries and a corresponding maturity Treasury yield, and by manipulating the spread via trading on ICAP a Defendant could manipulate the final ISDAfix. Similarly, manipulative trading on the US Treasury market influenced the other component of this sum, and therefore trading that moved the relevant US Treasury yield would have affected the ISDAfix. Finally, since Eurodollar futures prices and swap yields both incorporate the same LIBOR-based forward curves, prices in the two markets

[1] The Commodity Futures Trading Commission ("CFTC") also has alleged that ISDAfix was manipulated by trading Treasuries and Eurodollar Futures, as well as swaps. Commodity Futures Trading Commission, ORDER INSTITUTING PROCEEDINGS PURSUANT TO SECTIONS 6(c) AND 6(d) OF THE COMMODITY EXCHANGE ACT, MAKING FINDINGS, AND IMPOSING REMEDIAL SANCTIONS, 21 December, 2016.

are inherently linked, and deviations between prices in the two markets create arbitrage opportunities that are quickly eliminated: therefore, distortions in Eurodollar futures prices caused by manipulative trading in that market would have caused similar distortions in swap yields.

33. Furthermore, Plaintiffs allege that Defendants conspired and colluded to submit identical quotations to ICAP. More specifically, Defendants conspired and colluded to submit quotations equal to the Reference Rate. This conspiracy was crucial in making effective the manipulative "bang-the-fix" trading. This trading was intended to affect the Reference Rate. The agreement among Defendants to "rubber stamp" the Reference Rate ensured that successful manipulations of the Reference Rate were sufficient to manipulate the final ISDAfix. Absent such agreement, and adherence thereto, no Defendant could be sure that a costly attempt to influence the Reference Rate would move the final ISDAfix in a way that Defendant desired and profited from.

## IV. The Economics of Trade-based Manipulation

### A. Trades Impact Prices

34. Myriad peer-reviewed academic publications in the subfield of finance known as "market microstructure" show theoretically that trades in financial instruments should move the prices of those instruments, and provide extensive empirical evidence documenting the price impact of trades in diverse financial instruments, including stocks, bonds, futures, options and other derivative instruments. The insights and methodologies in this extensive literature can be utilized to derive methods for proving harm in the present matter on a class-wide basis, and for calculating damages suffered by Class Members.

35. The theoretical market microstructure literature demonstrates that there are two basic reasons why trades in a financial instrument move the price of that instrument. The first reason is that in most financial markets someone who wants to buy or sell a financial instrument must trade with an intermediary—a "market maker"—who is continuously present and is willing to buy (sell) when more investors want to sell than buy (buy than sell), and who incurs costs to provide this service.[2] The costs of providing the service include trade processing costs: the market maker uses labor and capital to route orders; execute, process, clear and settle trades; ensure regulatory compliance; and perform recordkeeping functions. Moreover, a market maker must often hold inventories of the financial instrument in order to be able to accommodate investor demands to buy or sell immediately (and at unpredictable times). Holding inventory subjects the market maker to price risk (the inventory's value falls or rises with market prices), and inventory must be financed, which is costly.

36. The market maker will not provide the service of being the counterparty to an investor who wants to buy or sell unless compensated for these costs. The compensation comes in the form of trading profits: the market maker buys from investors at a price that is lower on average than the price at which he sells to investors by an amount sufficient to cover trade processing and financing costs, and to compensate for risk. The necessity for intermediaries to earn trading profits to cover costs implies that trades impact prices. Prices fall when investors sell to the market maker, and rise when

[2] For an overview of the economics of market making, see inter alia, Hans Stoll, Friction, 55 J. of Finance (2000): 1479-1514 and Maureen O'Hara, Market Microstructure Theory (1995).

investors buy from the market maker. By buying low and selling high, the market maker earns a trading profit from which to pay the costs of providing market making services.

37. A crucial implication of this analysis of market making is that the price impacts of trades necessary to cover the market makers' operational costs are *temporary/transitory*. That is, prices fall (rise) when a market maker buys (sells), then bounce back when the market maker reverses the transaction. It is precisely this temporary price effect of trades—this "bounceback"—which generates the trading profit for the market maker that covers trade processing and financing costs.

38. Thus, one effect of purchases or sales of a financial instrument is a temporary movement in the price of this instrument that is reversed over time.[3]

39. The second reason why trades affect prices is that trades convey information about the value of a financial instrument. In particular, some investors have private information about the value of a security or a derivative instrument. They can use this information to trade profitably. But since this type of trading is a zero sum game, the informed traders' profits come at the expense of those who do not possess this information. Knowing that, less-informed traders realize that a particular trader *X* may want to buy from them (sell to them) because *X* has information that the current price of

[3] Institutionally, market makers quote a bid price at which they are willing to buy, and an ask (or offer) price at which they are willing to sell. Investors sell to the market maker at the bid, and buy from the market maker at the ask. As market makers buy and sell (i.e., investors sell to or buy from him) the price "bounces" between the bid and ask. That is, the price moves down temporarily when the market maker buys, and then bounces back up when the market maker sells, and *vice versa*. The investor pays the spread between the ask and bid as a cost of trading.

the instrument is too low (high).[4] Thus, purchases can signal bullish information, and sales can signal bearish information.[5]

40. In an efficient financial market, prices change to reflect the arrival of new information. Since purchases and sales convey information, transactions cause prices to move to reflect this information.

41. Crucially, in an efficient financial market information has *permanent* effects on prices. Contrary information may arrive subsequently, and cause a movement in price in the opposite direction, but the effect of the initial piece of information remains in the price long after the trade. For instance, a bullish piece of information about a stock that arrives today causes the price to rise today. A bearish piece of information that arrives tomorrow causes the price to fall tomorrow, but it falls from a higher level. Therefore, since (a) trades contain information, and (b) information has permanent effects on prices, trades can have permanent effects on prices.[6]

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[4] It is well known that no trading could take place in a market where information is the only motivation to trade: in that case, if someone offered to buy a financial instrument from you, you would know immediately that he wants to do that because the price you are asking does not reflect private information that he possesses. In such a world, only suckers would trade. However, there are many motives to trade. For instance, someone may be looking to invest a cash windfall, and is buying even though she does not have information that a financial instrument is currently undervalued. The price impact of a trade depends on the distribution of reasons for people to trade. Market participants attempt to estimate the likelihood that a particular trade occurred because one of the parties has better information, as opposed to some non-informational motive. The higher the likelihood that a trade occurred because one party had better information, the bigger the permanent price impact of the trade. See Paul Milgrom and Nancy Stokey, Information, Trade and Common Knowledge, 26 J. Econ. Theory (1982) 17.

[5] The risk of trading with someone who has better information is sometimes called "adverse selection."

[6] The understanding that when some traders have private information, that trades have permanent price impacts has been well-understood theoretically, and confirmed empirically, since the beginnings of the microstructure literature. In a seminal theoretical paper, Lawrence Glosten and Paul Milgrom, Bid, Ask and Transaction Prices In a

42. Thus, the market microstructure literature predicts that (a) trades in financial instrument affect the price of that instrument in the direction of the trade, with prices rising (falling) in response to a purchase (sale), and (b) some of the price impact is temporary and reverses over time, but some of the price impact is permanent and remains in the price long after the trade.

43. The theoretical and empirical microstructure literatures also demonstrate that quotes—bids and offers—can impact prices, and in particular can have permanent impacts on prices.[7] The reason for this is that it is often cheaper for traders with

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Specialist Market With Heterogeneously Informed Traders, 14 J. of Financial Econ. (1985) 71, trades have permanent price impact. In technical terms, Glosten-Milgrom show that prices changes in their model are not autocorrelated, and prices are a "martingale." This means that a trade moves prices, and conditional on all trades up to a given time, the best forecast of future prices is the current price. This is another way of saying that the information remains in the price forever. A similar result obtains in the other seminal theoretical microstructure paper, Albert S. Kyle, Continuous Auctions and Insider Trading, 53 Econometrica (1985) 1315, and the extension of the Kyle model to continuous time, Kerry Back, Insider Trading in Continuous Time, 5 Rev. of Fin. Stud. (1992) 387. The Glosten-Milgrom and Kyle models abstract from inventory and risk averse market-makers in order to derive the implications of privately informed trading: adding inventory and market maker risk aversion introduces temporary price impacts, but permanent price impacts remain as long as there are privately informed traders. The empirical literature focuses on quantifying the relative contribution of these components. For a summary of the theoretical and empirical literatures demonstrating that trades have permanent price impacts, see Bruno Biais, Larry Glosten, and Chester Spatt, Market Microstructure: A Survey of Microfoundations, Empirical Results, and Policy Implications, 8 J. Financial Markets (2005) 217. Maureen O'Hara, Market Microstructure Theory (1998). Joel Hasbrouck, Empirical Market Microstructure: The Institutions, Economics, and Econometrics of Securities Trading (2007). Thierry Foucault, Marco Pagano, and Ailsa Roell, Market Liquidity: Theory, Evidence, and Policy (2013). Richard K. Lyons, The Microstructure Approach to Exchange Rates (2006). See also Stoll *supra* note 2 ("[i]nformational trading results in permanent price changes" and "[p]rice changes associated with adverse information are permanent adjustments in the equilibrium price").

[7] Alex Boulatov and Thomas George, Hidden and Displayed Liquidity in Securities Markets With Informed Liquidity Providers, 26 Rev. of Fin. Studies (2013) 2095. Sugato Chakravarty and Craig Holden, An Integrated Model of Market and Limit Orders, 4 J. of Fin. Intermediation (1995) 213. Michael Fleming, Bruce Mizrach, and Giang

information to trade on that information through the submission of (passive) limit orders (bids and offers) rather than (aggressive) market orders. Thus, the flow of limit orders provides information, just as does the flow of market orders (and hence the flow of executed trades).

44. Furthermore, since the values of related financial instruments depend on some common fundamental factors, trades in one instrument (e.g., a five-year swap) can convey information that is relevant for the prices of other instruments (e.g., two-year and ten-year swaps). Thus trades in one instrument can have permanent impacts on the prices of related instruments.[8]

### B. Empirical Measurement of Price Impact

45. The empirical market microstructure literature has developed and refined methods for quantifying the price impact of trades. There are a variety of such methods, but the most common, and the one most directly applicable to the facts of the present litigation, is to measure price changes at various time intervals surrounding a trade. For instance, consider a purchase of a financial instrument at time *T*. The researcher measures the price of the instrument some time prior to the trade, such as *T* minus 120 seconds (or even one second): since a trade might not have occurred at *T* minus 120

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Nguyen, The Microstructure of a U.S. Treasury ECN: The BrokerTec Platform, FRBNY Staff Reports No. 381 (2017). Thierry Foucault, Sophie Moinas, and Eric Theissen, Does Anonymity Matter in Electronic Limit Order Markets, 20 Rev. of Fin. Studies (2007) 1707. Ron Kaniel and Hong Liu, So What Do Informed Traders Use, 79 J. of Bus. (2006) 1867. Bruce Mizrach, The Next Tick on Nasdaq, 8 Quant. Fin. (2008) 19. Praveen Kumar and Duane Seppi, Limit Order and Market Orders With Optimizing Traders, Carnegie-Mellon Working Paper (1993).

[8] Trades in one instrument can cause temporary price impacts in other instruments as well. For instance, a market maker who buys a five-year bond and takes it into inventory increases its exposure to interest rate risk and commits valuable capital. This may raise the risk and cost of inventories of related instruments like ten-year bonds that cause the market maker to be willing to trade these instruments at lower prices.

seconds, the researcher typically measures the price at this time as the midpoint between the bid and ask prices for the instrument at that instant. Then the researcher measures the price of the instrument (again often using the bid-ask midpoint) at various times after the trade, such as 30 seconds, a minute, five minutes, and ten minutes after the trade. The permanent impact of the trade is measured by the difference between the price some time after the trade (e.g., *T* plus five minutes) and the price prior to the trade (e.g., *T* minus two minutes). The immediate impact is measured by the difference between the maximum change in price between *T* plus (say) five minutes and the pre-trade price and the permanent price change (estimated as just described). In the empirical market microstructure literature, common choices of the time interval are 5 and 15 minutes.

46. Rates (prices) move for reasons other than manipulative trading. It is therefore common in the academic literature to utilize variables to control for these other factors. In the present context, the prices/yields of other fixed income instruments, or derivatives on fixed income instruments (e.g., futures on Ten Year US Treasury Notes) can be used as control variables. Swaps yields, the yields on Treasury securities (including derivatives on Treasuries), and the prices of other interest rate derivatives (e.g., Eurodollar futures, which have prices tied to three-month dollar LIBOR rates) all incorporate information relevant to the determination of interest rates (e.g., information on inflation, economic activity, or risk preferences). Therefore, using *inter alia* yields on Treasuries, Treasury derivatives prices, or Eurodollar futures prices to control for other factors that affect interest rate may permit a more precise determination of the impact of manipulative trading.

47. For example, manipulative trading in the swaps market intended to raise the ISDAfix for the two-year swap rate would tend to cause the two-year swap rate to rise relative to the yield implied by the futures price on the Two Year Treasury Futures contract. Therefore, an analysis of the change in the difference between the two-year swap yield and the yield implied by the price of the Two Year Treasury Futures contract at 10 second intervals between time *T* minus 60 seconds and *T* plus 5 minutes can be used to determine the temporary and permanent impact of manipulative trades intended to affect the ISDAfix on the two-year swap at *T*.

48. It may seem counterintuitive that it is standard in the extensive academic microstructure literature to measure permanent price impacts of a trade by the movements in price in the first few minutes after it occurs, but it is not. This is a direct consequence of information in an efficient market: efficient markets respond very quickly to the arrival of new information. Moreover, in an efficient market, prices do not overreact to new information, and then (partially) reverse after the initial reaction; if they did so consistently, that would make it profitable to trade on overreaction, and such trading would tend to eliminate any tendency to overreact and retrace. Furthermore, in an efficient market prices will not react gradually to new information: if they did so, again there would be a profit opportunity from continuing to trade after the news arrives. Thus information, regardless of whether conveyed by a news release or a potentially informed trade, should lead to a rapid price reaction, and the initial price reaction is neither systematically too big nor too small: it is (on average) just right. The immediate implication of this is that the immediate price response to a transaction (or a news release) is the best measure of the information embedded in it. This insight is at the basis

of not just the market microstructure literature, but the entire event study literature in corporate finance and asset pricing.

49. In real world markets, as noted before, there are other factors such as trade processing costs, inventory costs, and market maker risk aversion, that can cause trades to have transitory effects on prices. Because of these factors, it is not practical to estimate the permanent impact of a transaction by the change in price immediately following a trade, as the theoretical microstructure literature would imply in their absence. Instead, to detect the long-run impact it is necessary to measure the price some time after the trade in order to allow these temporary effects to dissipate. Looking at the price impact some minutes after the trade permits measurement of the information impact—the permanent impact—uncontaminated by temporary price effects.

50. In brief, the length of the post-trade time interval chosen is not related directly to the permanent impact: it is related to how long the *temporary* impacts last. It is desirable to choose the *shortest* time interval over which the temporary impacts dissipate. The shortest interval is desirable because new information can arrive over time after the trade of interest and cause price movements that make it more difficult to measure the impact of that trade. Again, for the purpose of measuring the permanent price impact of a transaction, shorter is generally better in order to increase the power of tests to detect the price impact of trades.

51. The results the analysis of price impact of Treasury trades on the BrokerTec platform presented in Section V *infra* demonstrates that the permanent impact of a trade can be measured in a relatively short time in that setting. In those results, the

permanent impact of a trade is manifest less than 20 trades later—which represents approximately one minute of trading time.

52. This methodology has been employed in literally hundreds of peer reviewed articles, studying myriad financial instruments including securities and derivatives.[9]

53. There are a variety of other methods for quantifying price impact, some of which are applicable to the allegations in this litigation, and which can be employed to establish causation, and in some of the alleged manipulative episodes, to quantify temporary and permanent impacts for the purpose of calculating damages. One such method is to estimate so-called "vector autoregressions" ("VARs") that quantify the relationship between trades (and orders) and price (rate) movements.[10] These models allow trades to impact prices, and prices to impact future trades. The salient feature of these models is that they can be used to quantify the permanent impact of transactions through the determination of "impulse response functions." In the present context, impulse response functions show how an unexpected trade affects prices over time,

[9] Representative examples include: A. Kraus and Hans Stoll, Price Impacts of Block Trading on the New York Stock Exchange, 27 J. of Finance (1972) 569. Roger Huang and Hans Stoll, Dealer Versus Auction Markets: A Paired Comparison of Execution Costs on NASDAQ and NYSE, 41 J. of Financial Econ. (1996) 313. Hendrik Bessembinder and Herb Kaufman, A Cross-Exchange Comparison of Execution Costs and Information Flow for NYSE-listed Stocks, 46 J. of Financial Econ. (1997) 293. Ananth Madhavan and Minder Cheng, In Search of Liquidity: Block Trades in the Upstairs and Downstairs Markets, 10 Rev. of Financial Studies (1997) 175. Hendrik Bessembinder, Issues in Assessing Execution Costs, 6 J. of Financial Markets (2003) 233.

[10] Joel Hasbrouck, Trades, Quotes, Inventories, and Information, 22 J. of Financial Econ. (1988) 229. Joel Hasbrouck, Measuring the Information Content of Stock Trades, 46 J. of Finance (1991) 179.

taking into account the feedback between trades and prices.[11] The impulse response function often becomes effectively constant after some number of trades, or after some period of time: the price change at which the impulse response function flattens out is used in the academic literature to estimate permanent price impact.

54. These methods can also be used to estimate the impact of limit orders on prices.

55. Other methods measure permanent price impacts due to information effects and transitory movements due to inventory and other effects using bid-ask spreads and price movements in response to trades. The intuition behind these methods is that the bid-ask spread must compensate market makers for losses to informed traders and for the costs of holding inventory and processing trades. As noted earlier, information-based trading has permanent impacts on prices whereas inventory and processing costs result in transitory impacts. Data on spreads, the mid-point between the bid-ask, and price changes can be used to decompose spreads and price changes into these different components. The temporary component can be used to quantify the expected immediate impact of a manipulative trade, and the information-based component can be used to estimate the permanent impact of a manipulative trade.[12]

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[11] Trades are typically predictable. For example, buys tend to follow buys. (In econometric argot, trades are positively autocorrelated.) Similarly, price changes in one period often have power to predict future trades. Impulse response functions quantify the impact of the unpredicted component of transactions.

[12] Some representative examples include Lawrence Glosten and Lawrence Harris, Estimating the Components of the Bid-Ask Spread, 14 J. of Financial Economics (1985) 71. Ananth Madhavan, Matthew Richardson, and Mark Roomans, Why Do Security Prices Change? A Transaction-Level Analysis of NYSE Stocks. 10 Rev. of Financial Studies (1997) 1035, and Roger Huang and Hans Stoll, The Components of the Bid-Ask Spread: A General Approach, 10 Rev. of Financial Studies (1997) 995. See Stoll, *supra* note 2 for a review of the literature.

56. All of these methods are widely used in the peer reviewed academic microstructure literature. The applicability of each depends in part on data availability. The VAR and impact decomposition methods require accurately time-stamped and sequenced information on trades, prices, and bid and ask quotes.

57. These methods have been applied to the fixed-income markets, particularly the market for United States Treasury securities. The academic studies of the Treasury market document that trades (and quotes) have permanent effects on prices.[13] Moreover, these studies document that price impact is increasing in trade size: bigger trades have a bigger impact on prices. The most notable study specifically analyzes the BrokerTec platform operated by Defendant ICAP upon which Plaintiffs allege that Defendant Dealers executed manipulative transactions to "bang the fix." This study finds that trades (and quotes) have permanent price impacts for all maturities examined.

**C. Manipulative Trading**

58. The fact that trades impact prices makes possible manipulative trading strategies, i.e., trading strategies that are intended to, and have the effect of, causing prices to diverge from their competitive values that accurately reflect information available at a particular point in time.

59. Since a trade impacts prices in the direction of the trade, a party who desires to cause the price of a financial instrument to increase (decrease) can do so by buying (selling) that instrument. Since others in the marketplace do not know the motive

[13] Michael Brandt and Kenneth Kavajecz, Price Discovery in the U.S. Treasury Market: The Impact of Order Flow and Liquidity on the Yield Curve, 59 J. of Finance (2004) 2623. Michael Fleming, Measuring Treasury Market Liquidity, 9 Federal Reserve Bank of New York Policy Rev. (2003) 83. Onem Ozocak, Price Impact of Informed Trades in the U.S. Treasury Markets, 3 J. of Econ. and Financial Studies (2015) 29, Fleming et al, *supra* note 7.

for that transaction, they will attempt to assess the motive based on past experience (e.g., what is the likelihood that the trade is due to the existence of private information), and this assessment will determine the permanent impact of the trade. The immediate impact will depend on the costs that intermediaries incur in order to process, finance, and bear the risk of the transaction.[14]

60. Therefore it is always possible to drive the price of a financial instrument up by buying it, or down by selling it. There remains the question of whether trades

[14] Praveen Kumar and Duane Seppi, Futures Manipulation With Cash Settlement, 47 J. of Fin. (1992) 1485 presents a modification of the canonical Kyle microstructure model that is closely related to the allegations in this case. In Kumar-Seppi, a manipulator accumulates a position in a cash-settled derivative contract (of which a cash-settled swaption is an example) that is settled against the price of the underlying instrument (a swap, in the case of a swaption). The manipulator then trades in the underlying market around the time that the settlement price of the derivative is determined (e.g., trading swaps on ICAP prior to 11:00AM on a day a swaption settles against ISDAfix). By moving the price in the underlying market, the manipulator earns a profit on the derivative. Because the model is a variant of the Kyle model, the price impact of the trading in the underlying instrument is permanent: in the model, the forecast of the value of the instrument is a function of the size of the manipulator's trade in the underlying instrument. Carole Comerton-Forde and Talis J. Putnins, Measuring Closing Price Manipulation, 20 J. of Financial Intermediation (2011) 135 present empirical evidence on the price effects of 184 manipulations of the closing prices on US and Canadian stock exchanges. During these manipulations, traders bought large quantities of stock shortly before the close. Comerton-Forde and Putnins find that (a) stock prices rose significantly at the close, and (b) the increases were only *partially* reversed the next day. The fact that the reversals were only partial indicates that the manipulations had a permanent effect on prices. Craig Pirrong, The Economics of Commodity Market Manipulation, 5 J. of Commodity Markets (2017) 1 reviews the literature on trade-based manipulation, and presents empirical evidence related to the alleged "bang the settlement" manipulation by the trading firm Optiver. See FINAL CONSENT ORDER OF PERMANENT INJUNCTION, CIVIL MONETARY PENALTY AND OTHER RELIEF AS TO DEFENDANTS OPTIVER US et al, SDNY 08 Civ. 6560, 2012. (Optiver agreed to pay $14 million in fines and disgorgement.)

intended specifically to move the price are in fact profitable: just because something is possible does not mean it is profitable.[15]

61. Trading with the intent to move price is always costly. The temporary price impact of the trade is a cost to the price-moving trader. For instance, if a purchase of a stock drives up the price temporarily by $.1/share, the buyer pays the higher price, but sells later at a price that is (on average) more than $.1 lower because the price reverses at some time after the purchase: the sales price is more than $.1 lower because the subsequent sale drives the price down.

62. Absent some source of profit that would offset this cost, trades intended to move the price of a financial instrument would be unprofitable to undertake. However, moving the price can be profitable if the prices of, or cash flows accruing to, other instruments depend on the price of the financial instrument. In the present litigation that is the case. For example, Defendants had positions in cash-settled swaptions that had payoffs/cash flows that were determined based on the ISDAfix rates. Consider a Defendant with a position in a swaption that generated a higher payoff when the ISDAfix two-year swap rate is higher. By buying the two-year swap in the market prior to the setting of the Reference Rate, the Defendant could drive up the market two-year swap rate, which would drive up the Reference Rate, which would drive up the ISDAfix rate (especially in the presence of a conspiracy among submitters to rubber stamp the Reference Rate) which would increase the payoff to the Defendant's swaption. Depending on the size of the swaption position, the size of the trade necessary to move

[15] The objective of the alleged manipulations was to affect interest rates. Since rates vary inversely with prices, a manipulator attempting to drive up (down) the rate (yield) on Treasury securities would sell (buy) them.

the market swap rate, and the magnitude of the temporary price impact of the trade, this could be profitable for the Defendant even though the transaction in the swap alone would be unprofitable.

63. That is, the ISDAfix process created an incentive to engage in transactions to move prices, and to conspire to rubber stamp prices, even if the transactions were unprofitable on a stand-alone basis. This is a classic form of manipulation: losing money on one trade or position in order to make more money on a related trade or position.

64. This manipulative trade would have profited the Defendant's swaption position. Since the swaption is zero sum—every dollar one party makes is a dollar lost by the counterparty—the Defendant's profit on the swaption damaged its counterparty, dollar-for-dollar.

65. It is important to note that even though the intent of a particular manipulative transaction may have been to affect a particular ISDAfix rate, the damages arising from this manipulation are not limited to the Defendant's counterparties in instruments tied to this ISDAfix rate. Any market participant with the same exposure to the ISDAfix rate as the Defendant's swaption counterparty (i.e., any other participant with a position that lost money as a result of the movement in the ISDAfix rate that profited the manipulating Defendant) is damaged.

66. Furthermore, since trades in one instrument can affect the prices of other, related instruments, a manipulative trade in one instrument (e.g., the two-year swap) could affect the ISDAfix rates for other tenors, thereby damaging those with positions tied to those other ISDAfix rates.

67. Moreover, since trades in one instrument (e.g., the two-year swap) can have permanent effects on the price of that instrument, and other related instruments, a manipulative trade prior to a particular ISDAfix could impose damages on those trading that or related instruments long after the manipulative trade.

68. The existence of permanent effects has another important implication. Specifically, permanence implies that the impact of manipulative acts is cumulative when Defendants commit multiple such acts. This further implies that it is necessary to examine all such acts collectively, and that it is a category mistake to examine the impact of single events in isolation. This implies in a case with multiple manipulative events that affect multiple instruments and plaintiffs, a class-wide approach is superior to any approach that focuses on individual acts of manipulation, individual transactions, or individual plaintiffs.

## V. Quantifying the Artificiality Caused by "Bang-the-Fix" Trading

### A. Methodology Overview

69. The peer reviewed academic literature discussed at Section IV *supra* provides a template that can be utilized to establish liability and determine damages on a class-wide basis. The analysis proceeds a series of basic steps.

70. First, it is necessary to identify a set of manipulative events. The remaining steps in the process described below can be applied to any such list, and adjusted to reflect those that the trier of fact accepts as manipulative. For the purposes of this report, counsel has asked me to use the events described in the report of Mr. Farrell as a "sample" of days to demonstrate implementation of the methodology.

71. Second, a widely utilized methodology for quantifying the price impact of trades is applied to a set of transactions identified as manipulative. This analysis quantifies the temporary and permanent impacts of each manipulative transaction. The immediate impact quantifies the effect of the manipulative trade on the ISDAfix immediately following that trade. The permanent impact quantifies the effect of the manipulative trade on market rates subsequent to when the pivotal Reference Rates were determined. This is discussed in more detail in Section V.B *infra* (regarding the temporary impact that trades have on a particular day's rates at 11:00AM, and thus on ISDAfix rates due to rubberstamping), in Section V.C *infra* (regarding the permanent impact that trades have on rates), in Section V.D *infra* (discussing my preferred approach regarding the use of "controls" in the transitory and permanent impact analyses), and in Section V.E *infra* (which provides an example of the calculations for a particular "bang the fix" episode).

72. Third, given the estimate of how a manipulative trade impacted on a permanent basis, a "ribbon" of "but-for" swap rates can be created (as discussed in Section V.F *infra*).

73. Fourth, this "artificiality ribbon" can then be applied either to particular transactions, or entire databases of transactions, using formulaic, industry-standard techniques, as discussed in sections VI, VII, and VIII *infra*.

### B. Quantifying the Immediate Impact of "Bang the Fix" Trades

74. The first step of the analysis is to identify manipulative trades. It is possible to do this on a class-wide basis as follows.

75. Traders employed by the bank Defendants routinely engaged in communications (text messages, Bloomberg messages, Bloomberg chats, emails, and recorded phone conversations) with ICAP brokers, and with other traders. In some conversations, a trader told the ICAP broker or another trader of his (or her) desire to move a particular rate at the fixing, and disclosed his (or her) intentions to trade prior to the 11:00AM fixing in order to achieve that objective.

76. Plaintiffs' experts will review documentary evidence (by which I also mean recorded conversations) produced in this matter, and identify communications that indicate that a trader intended to manipulate an ISDAfix, or that manipulative trading activity occurred. I will rely on these experts to identify communications that indicate that a trader intended to bang-the-fix, or that such an attempt had occurred, though the final list will be that determined by the trier of fact.

77. Once a particular manipulation episode is identified, the standard peer reviewed methodology described above can be implemented to determine the impact of that manipulation on the rate on the 19901 screen at the time of the fix on the date the manipulation occurred. Since under the alleged conspiracy to rubber stamp the Reference Rate the final ISDAfix was equal to that rate, the impact of the manipulation on the ISDAfix can be determined by quantifying the impact of the manipulative trading on the Reference Rate, using the standard methodology.

78. The set of bang-the-fix events identified by Mr. Farrell will constitute the sample of potential manipulations that I will use to demonstrate the implementation of the methodology. In this demonstration, and at trial, I will then subject these events to an additional filter that reflects the possibilities that although the communications reveal that

a trader disclosed his or her intent to bang-the-fix in a particular rate in a particular direction, (a) no such attempt actually occurred, or (b) this attempt was not successful. This filter is based on the observation that a successful manipulation attempt would cause at least a temporary impact on the rate the trader stated he wanted to move in the direction that the trader stated she or he wanted to move it.

79. Specifically, I will exclude from consideration potential manipulations identified from Defendants' communications in which the methodology described at ¶¶83-90 *infra* does not show that the allegedly manipulated rate moved in the direction disclosed in the communication during the period from sometime before the manipulative trading occurred and the time the Reference Rate was determined. Thus, the final set of manipulative episodes that will be utilized to determine damages on a class-wide basis will be those disclosed in communications, and for which the rate identified in the communication moved in the direction identified in the communication during a time window ending at 11:00AM.

80. Hereafter I will refer to this as the "immediate impact filter."

81. As noted at ¶44 *supra* a bang-the-fix manipulation of one tenor can potentially affect rates for other tenors. Because of the potential for spillovers, it is necessary to calculate this market swap rate movement for all tenors on each manipulation date, using the methodology described at ¶¶83-90 *infra.* I also apply an immediate impact filter across tenors. For example, if documentary evidence shows the two-year rate was manipulated upwards and the two-year rate passes the immediate impact filter on the manipulation date, the artificiality ribbon for the five-year rate will be adjusted on the manipulation date if the five-year rate also rises at the time of the fix.

Conversely, if the directly manipulated rate (e.g., the two-year rate) and the rate on another tenor (e.g., the five-year) move in opposite directions, the artificiality ribbon on the other tenor will not be adjusted.

82. The documentary evidence detailed by Mr. Farrell documents that Defendants attempted to move a particular rate in a particular direction. However, there are instances in which the communications indicate an attempt to manipulate the spread (i.e., the difference) between two rates. In these instances, the immediate impact filter will not be applied to other rates.

83. There are two methodologies for establishing this impact. One methodology ("Methodology 1") does not control for other possible causes of movements in interest rates that could affect the rate on the 19901 screen. The other methodology ("Methodology 2") does control for other possible causes. Both methods are employed in the academic literature.

84. Specifically, under Methodology 1, the impact of the manipulative trading activity on the Reference Rate is equal to the difference between the market swap rate (measured by the bid-ask midpoint) at the time the Reference Rate is determined and the market swap rate sometime prior to the commencement of the anomalous trading (and/or the time of any communication indicating or planning an attempt to "bang-the-fix").

85. Under Methodology 2, the impact of the manipulative trading activity on the Reference Rate is equal to the difference between the market swap rate (measured by the bid-ask midpoint) at the time the Reference Rate is determined and the market swap rate sometime prior to the commencement of the anomalous trading (and/or the time of

any communication indicating or planning an attempt to "bang-the-fix"), minus the change in a control interest rate over this same time period.

86. There are a variety of different control rates. One example is the yield implied by the price of the Treasury Futures contract with a similar maturity to the allegedly manipulated rate. For example, if a communication indicates an intent to manipulate the 5-year swap yield, the yield implied by the price of the next to mature Five Year Treasury Futures contract can be utilized as a control variable.[16]

87. Treasury futures are traded continuously on the Globex system operated by the Chicago Mercantile Exchange Group. Trading volume is very heavy, usually making it possible to determine transaction prices at one-second (or lower) intervals. Moreover, CME Group disseminates data on the best bid and best ask on each Treasury futures contract. For the nearby contract there is always a bid and offer outstanding, thereby making it possible to determine a bid-ask midpoint at any desired frequency (e.g., one second, or less).

[16] Treasury Futures contracts utilize a conversion factor system. Each note or bond eligible for delivery under a particular is assigned a conversion factor that gives the flat price one dollar principal amount of that security if it is priced to yield 6 percent to maturity. Given the futures price, and the coupon and maturity on the so-called "cheapest-to-deliver" security, it is possible to determine the yield on this security. This yield can be used as a control rate. Alternatively, a yield can be calculated from the futures price based on the assumption that it is the price of a Treasury security with a coupon of 6 percent, and a maturity equal to that stated in the futures contract (e.g., 5 years for the Five Year Treasury Futures contract). Although some swaps for which an ISDAfix was determined were for maturities matching the maturities in futures contracts (i.e., 2, 5, 10 and 30 years), others (e.g., 3 or 7 years) were not. For such swaps, it is straightforward to use maturity-weighted averages of the yields derived from futures prices as control variables. For example, a maturity weighted average of the yields derived from Two Year Treasury Futures and Five Year Treasury Futures can be used as a control variable in an analysis of an alleged manipulation of a three-year swap yield.

88. Another potential control variable is a synthetic swap yield derived from Eurodollar futures prices. Each Eurodollar futures price equals 100 minus a forward three-month interest rate (where the three month period commences at the expiration of a Eurodollar futures contract, which occurs on a March-June-September-December expiration cycle). Using standard bond mathematics, these forward rates can be used to determine a synthetic swap yield. For example, using standard bond math, the twenty Eurodollar futures prices expiring in the next five years can be used to determine a synthetic five-year swap yield that can be used as a control rate in the analysis of an alleged manipulation of the five-year ISDAfix rate.

89. Like Treasury futures, Eurodollar futures are traded continuously on the Globex system operated by the Chicago Mercantile Exchange Group. Trading volume is very heavy, usually making it possible to determine transaction prices at one-second (or lower) intervals. Moreover, CME Group disseminates data on the best bid and best ask on each Eurodollar futures contract. For the nearby contract there is always a bid and offer outstanding, thereby making it possible to determine a bid-ask midpoint at any desired frequency (e.g., one second, or less). Again, given these bid-ask midpoints, it is possible to construct synthetic swap yields that can be used as control rates.[17]

[17] Eurodollar futures bid and ask data is not available for all maturities throughout the class period. Therefore, it will be possible to utilize Eurodollar futures to determine a control rate for only a subset of the sample of alleged manipulations. Treasury futures will be used for those manipulations for which Eurodollar futures price data are not available.

90. For the purposes of producing an example artificiality ribbon, in this report as discussed *infra* I have chosen to use a Combined Methodology that incorporates the results of both Method 1 and Method 2 analyses. In constructing the Method 2 analysis for this report, I have utilized Eurodollar futures as the control where available, and Treasury futures where they are not. Eurodollar futures are closely related to swaps, and Treasuries are used as a basis in the calculation of swap rates. Furthermore, these data are of high quality, are based on actual transactions and actionable bids and offers, and are sequenced exactly.

### C. Quantifying the Permanent Impact of "Bang the Fix" Trades

91. As noted at ¶¶39-44 *supra*, manipulative trades undertaken to "bang-the-fix" may have impacts on market rates long after the fix was manipulated. Thus, post-fix market rates were potentially artificial, and market participants trading at those artificial rates were also potentially damaged. The standard market microstructure methodology can be utilized to quantify that artificiality and determine damages.

92. Specifically, a widely accepted and utilized academic methodology will be employed to calculate the permanent impact of every manipulative "bang-the-fix" episode identified as described at ¶¶74-90 *supra*: only episodes that survive application of the immediate impact filter will be considered. Using the methodology developed in peer reviewed market microstructure research, the permanent impact is the difference between the market rate 5 minutes after the establishment of the Reference Rate for that episode, and the market rate immediately prior to the "bang-the-fix" trading. Since (a) market microstructure theory shows that immediate impacts should exceed permanent impacts, and (b) due to random movements in rates the difference between the market

rate 5 minutes after the fix and the rate immediately prior to the bang-the-fix trading can exceed the immediate impact, I cap the permanent impact at the level of the immediate impact.

93. This permanent impact can be calculated using Methodology 1 (no use of control rates) or Methodology 2 (use of control rates). As noted at ¶¶86-90 *supra*, there are multiple potential control rates. Even though there are multiple such control rates, each can be applied on a class-wide basis.

94. Since there are multiple "bang-the-fix" episodes, and each episode may have a permanent impact, these impacts cumulate over time. Therefore, to determine the relevant but-for rates on each day in the Class Period, it is necessary to add the permanent impact of each episode of manipulative trading to determine the cumulative artificiality. The value of cumulative artificiality on any date can be subtracted from the actual rate on that date to determine the but-for rate.

95. This is best illustrated by a simple example. Assume that on Day 1, "bang-the-fix" trading causes a permanent price impact of +1 basis point. On Day 3, there is another "bang-the-fix" episode that causes another +1 basis point permanent impact. Finally, on Day 10, a "bang-the-fix" trade causes a permanent impact of -1 basis point.

96. In this scenario, cumulative artificiality from the fix on Day 1 until the fix on Day 3 is +1 basis point. From the fix on Day 3 until the fix on Day 10, the cumulative artificiality is +2 basis points. Subsequent to the fix on Day 10, the cumulative artificiality is +1 basis point.

97. Subtracting this cumulative artificiality—"the artificiality ribbon"—from the observed market rate produces the but-for rate on every day of the Class Period. Then, the damage for each Class Member can be determined by (a) subtracting the value of the instrument based on the actual market rate from the value of the instrument based on the but-for rate on the date of purchase, (b) subtracting the value of the instrument based on the but-for market rate from the value of the instrument based on the actual rate on the date of sale, and (c) adding the amounts in (a) and (b). The amount in (a) measures any overpayment at the date of purchase. The amount in (b) measures any shortfall at the date of sale.[18] I describe this methodology in more detail *infra*.

98. The artificiality ribbon will be the same for all Class Members, and it will be produced using the same methodology consistently throughout the Class Period. Since different Class Members have different exposures to artificiality (because they have different positions), their damages will differ. However, each Class Member's damages can be calculated using the same artificiality ribbon, and the appropriate formulae for translating that artificiality into damage, based on information provided by Defendants and the Class Member in Proofs of Claim.

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[18] The amount in (a) or the amount in (b) or both may be negative, indicating that the Class Member realized some gains due to artificiality. I take no position on the propriety or legal treatment of whether compensable "damages" are the sum, particularly where the sum is a positive number. I similarly take no position on the treatment of a situation where a Class Member has multiple transactions. The models are I discuss herein, however, are well-equipped to calculate the appropriate sum under any prescribed legal regime: it is a matter of arithmetic, with the only question being a legal one of what is to be included in the calculation.

**D. Combining Methodologies**

99. The nature of the manipulations alleged in this case make it reasonable, and preferable, to combine Methodology 1 and Methodology 2 to create an Integrated Methodology.

100. Using a control (as in Methodology 2) corrects for factors other than manipulation that can cause rates to move. However, in the present matter Plaintiffs allege that Defendants sometimes manipulated by trading instruments other than the swap spread (e.g., Treasuries). Manipulations undertaken by trading other instruments could move the control variables used in Methodology 2 in the same direction as the manipulation. This would (a) reduce the likelihood of detecting actual manipulations (i.e., it would generate "false negatives," which I discuss in more detail at ¶¶119-123 *infra*), and (b) reduce the measured impact of the manipulation.

101. To address these issues, Methodologies 1 and 2 can be combined as follows. First, any manipulative event identified from documentary evidence that passes the Immediate Impact Filter for either adjusted or unadjusted rate movements will be utilized to increment the artificiality ribbon. Second, the maximum immediate impact (taking account of the direction of the manipulation) will be used to determine the immediate impact of a particular manipulative event. Third, the maximum permanent impact (taking account the direction of the manipulation) will be used to determine the permanent impact, and to increment the artificiality ribbon: if the measured permanent impacts are in the opposite direction of the manipulation (as disclosed in the documentary evidence), the permanent impact will be set to zero.[19]

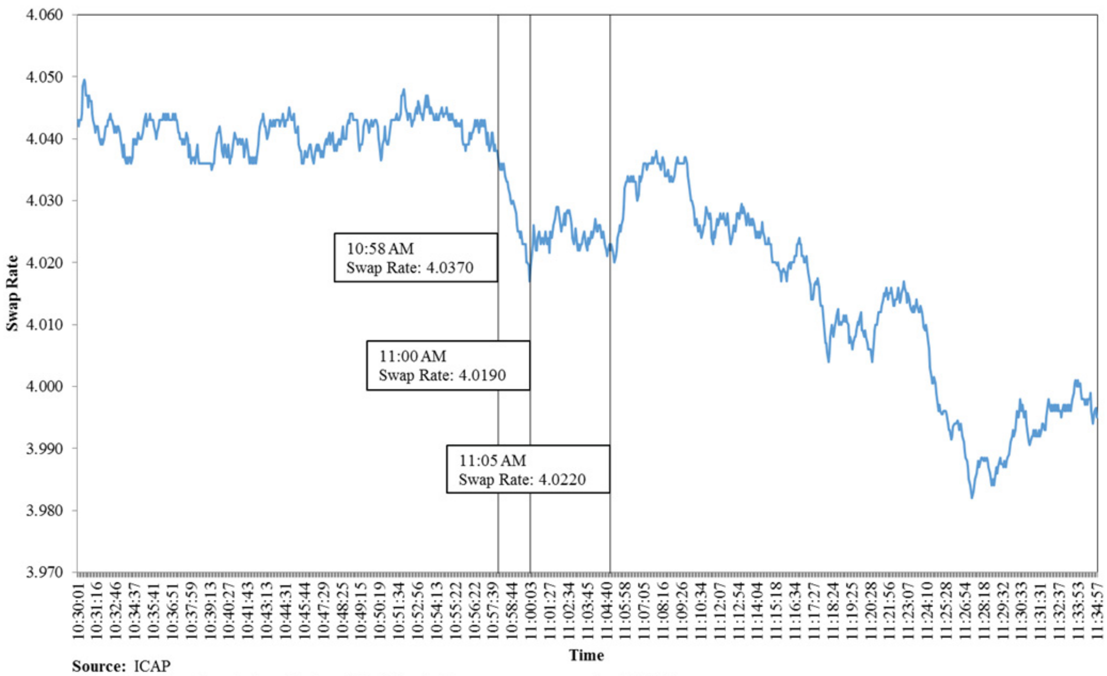
[19] If the Court or trier of fact finds the combined approach inappropriate, the methodologies can be applied to a list of manipulation events refined to include those that

### E. An Illustration of Quantifying Immediate and Permanent Impacts

102. A manipulative episode from 17 March, 2008 demonstrates how this methodology can be implemented to estimate the impact of bang-the-fix trading on a class-wide basis. I understand this date was selected based on an admission by a trader at Citi that [redacted] Thus, the chat indicates to Mr. Farrell an intent to "bang the fix" in order to drive downward the ISDAfix rate on the ten-year tenor.

103. The 19901 screen data from 17 March, 2008 shows a sharp move downwards in the ten-year rate around 11:00AM. See Figure 1:

**Figure 1**
**Price Impact on March 17, 2008**
**Manipulation Downwards of 10 Year Tenor**




**Source:** ICAP
**Notes:** The Swap Rate is the midpoint of the bid and ask swap rate quotes on the 19901 Screen.

104. Note that the rate moves downwards sharply after 10:57AM, and reaches its minimum exactly at 11:00AM. Thereafter, the rate rebounds somewhat, but remains

only "pass" under different presumptions. This again shows the flexibility and adaptability of the models described herein.

depressed below the level that prevailed prior the window I understand that Mr. Farrell found that most chats indicated "bang-the-fix" transactions were timed to occur. This pattern is characteristic of the price impact of trades that has been documented extensively in the academic literature: trading causes prices (or, in this case rates) to move in the direction of the trade; the impact reaches its maximum around the time the trading ends; prices (rates) then reverse, but do not revert completely to their pre-trade levels.

105. I have implemented the methodology described above to demonstrate how it can be used to quantify temporary and permanent price impacts. The results are summarized in Table 1:

**Table 1**
**Price Impact on March 17, 2008**
**Manipulation Downwards of 10 Year Tenor**

| | Calculation | Price Impact |
|---|---|---|
| Swap Rate at 10:58AM | [a] | 4.0370 |
| Implied Swap Rate at 10:58AM | [b] | 3.3707 |
| Implied Rate Source | | Treasury Futures |
| **Temporary Impact** | | |
| Swap Rate at 11:00AM | [c] | 4.0190 |
| Temporary Price Impact, Unadjusted (BPS) | [d] = 100*([c] - [a]) | -1.80 |
| Implied Swap Rate at 11:00AM | [e] | 3.3703 |
| Implied Swap Rate Change (BPS) | [f] = 100*([e] - [b]) | -0.04 |
| Temporary Price Impact, Adjusted (BPS) | [g] = ([d] -[f]) | -1.76 |
| **Permanent Impact** | | |
| Swap Rate at 11:05AM | [h] | 4.0220 |
| Permanent Price Impact, Unadjusted (BPS) | [i] = 100*([h] -[a]) | -1.50 |
| Implied Swap Rate at 11:05AM | [j] | 3.3700 |
| Implied Swap Rate Change (BPS) | [k] = 100*([j] - [b]) | -0.07 |
| Permanent Price Impact, Adjusted (BPS) | [l] = ([i] - [k]) | -1.43 |

**Notes:**
[1] Swap Rates are the midpoint of the bid and ask swap rate quotes on the 19901 Screen.
[2] Implied Swap Rates are calculated using Treasury Futures rates.
[3] Price Impacts are reported in basis points (BPS).
[4] Price Impacts are adjusted by subtracting the change in the Implied Swap Rate from the Price Impact.
**Sources:**
ICAP, Chicago Mercantile Exchange

106. In brief, the ten-year swap rate indicated on the 19901 screen at 10:58AM was 4.037 percent. The swap rate implied by Treasury futures was 3.3707 percent. By the time of the fix at 11:00, the swap rate had decreased by 1.80 basis points. Thus, under Methodology 1, the temporary price impact was 1.80 basis points. Over this time interval, the swap rate implied by futures prices declined by .04 basis points. Thus, under Methodology 2, the immediate impact was 1.76 basis points. Moreover, this episode survives the immediate impact filter under both methodologies.

107. To determine the but-for swap rate used to quantify damages on transactions that were settled against the ten-year ISDAfix Rate, under Methodology 1, 1.80 basis points would be subtracted from the cumulative permanent impact from the beginning of the Class Period until this new "bang the fix" event. This sum would then be subtracted from the relevant ISDAfix rate actually published on 17 March, 2008. Under Methodology 2, 1.76 basis points would be subtracted from the cumulative permanent impact from the beginning of the Class Period until this new "bang the fix" event. This sum would then be subtracted from the day's published ISDAfix rate.

108. Consistent with the academic literature, I will use the rate prevailing some time after 11:00AM to measure price impact. In Table 1, I use the rate at 11:05AM for this purpose. At 11:05AM, the ten-year swap rate was 4.022 percent, and the futures-implied swap rate was 3.37 percent. Thus, the change in the ten-year between 10:58AM and 11:05AM, a measure in the permanent impact under Methodology 1, was 1.5 basis points. Further, the change in the difference between the actual and implied swap rates over this time period was 1.43 basis points: this is a measure of permanent impact under Methodology 2. To obtain the new cumulative permanent impact following this "bang the fix" event until the next one, these amounts (1.5 or 1.43 basis points) would be subtracted from the cumulative permanent impact that had been calculated for all prior manipulations in the Class Period.

109. This approach leads to estimates of price impact every manipulation date, and for every date during the Class Period. These estimates are common to all Class Members, and will be used to determine class-wide estimates of but-for rates for each tenor and each day of the Class Period. These common but-for rates will be used as

inputs to standard pricing models in order to quantify damages on all relevant transactions, as discussed in Section VI and VII *infra*.

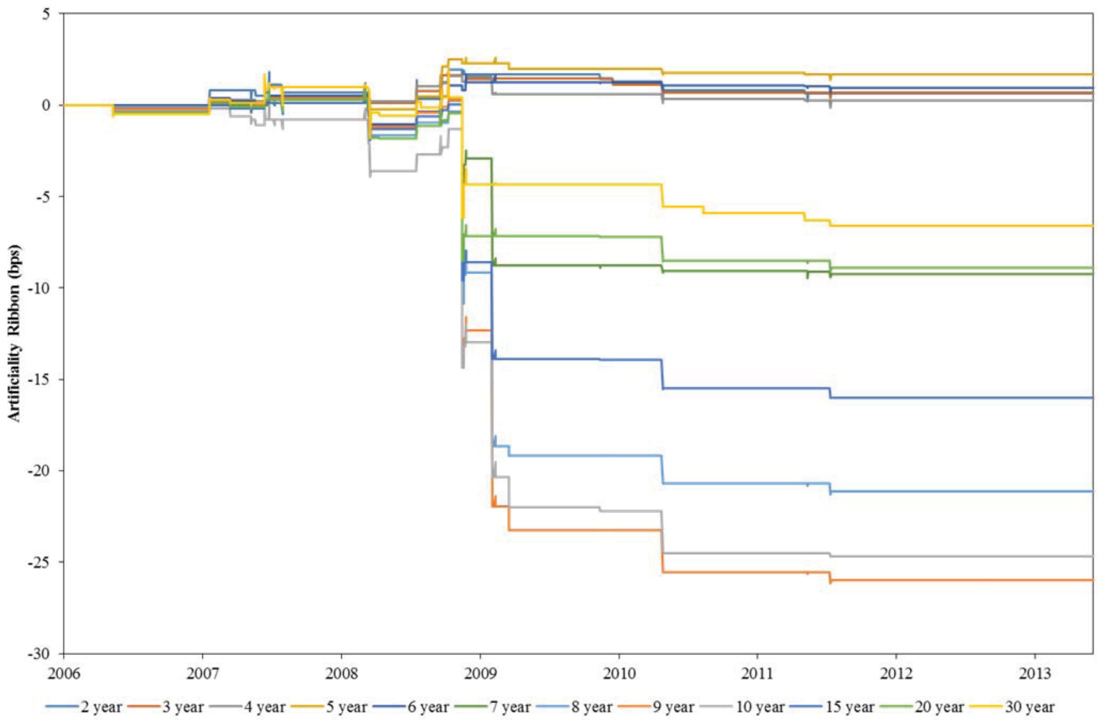
### F. An Illustration of the Implementation of the Artificiality Ribbon

110. Based on a provisional list of potential manipulation dates supplied by Mr. Farrell, I have implemented the rate impact quantification methodology for each date, and constructed an artificiality ribbon based on the Combined Methodology.

111. I understand that this list is just a sample of the instances in which trades were allegedly undertaken with the purpose of impacting ISDAfix rates. I use this list merely for the purpose of showing how the methodology can be used to create a "but for" "artificiality ribbon," which would be the same for all Class Members, from a set of manipulative events, and is not a final, definitive, or exhaustive list.

112. The illustrative artificiality ribbon for all tenors is presented in Figure 2.

**Figure 2**
**Artificiality Ribbons, By Tenor**




113. Note that in the figure there are discontinuous changes in the artificiality ribbons. The discontinuous changes correspond to manipulation dates that survive the immediate impact filter. There are also flat portions in the ribbons. These correspond to periods of time during which no new acts of banging the fix on the provisional list that survived the application of the impact filters.

114. It should be noted that the flatness of the line in the above chart does not mean the conspiracy was not causing damages, for multiple reasons. First, I understand the allegation is that the conspiracy operated on every day during the Class Period, by way of "rubber stamping." Thus, every ISDAfix rate during the Class Period was artificial, even if due to the limitations of discovery and trader behavior a corresponding "chat" is not located. Second, this is because the above chart is merely to illustrate how the model works based on a sample of dates. With further discovery and analysis, the

lines will change as additional instances of active manipulation are charted. Third, this is because permanent effects of prior acts continued to future dates—so even the "flat" parts represent damages as long as the line is not at "0."

115. Further note that there are often "spikes" in the series in which the artificiality ribbon moves in one direct and then retraces most, but not all, of that movement. For example, consider the ten-year tenor on 17 March, 2008. The artificiality in the rate moves from -2.1 basis points down to -3.9 basis points, and then moves back to -3.6 basis points, where it remains until 16 July, 2008.

116. The movement from -2.1 to -3.9 (a movement of -1.8 basis points) represents the temporary impact due to a manipulation on 17 March, 2008: in implementing the damages calculation, the artificiality of -3.9 basis points would be used to estimate the impact of this manipulation on instruments with payoffs tied to the ten-year tenor ISDAfix on 17 March, 2008. The artificiality of -3.6 basis points would be used for the calculation of damages on ten-year instruments from 18 March, 2008 through 16 July, 2008.

## G. Reliability of the Methodology

117. Any empirical methodology like that described *supra* is potentially vulnerable to "false positives" and "false negatives." In the present matter, a "false positive" would occur when there was in fact no manipulation in a particular maturity on a particular date, but it is identified as such. A "false negative" would occur when a manipulation in fact was attempted in a particular maturity on a particular date, but this episode was not included in the sample of manipulations analyzed. The methodology set out above is expressly designed to reduce the prevalence of false positives. Furthermore,

applying rigorous criteria to reduce the incidence of false positives necessarily makes the methodology more prone to false negatives. It must be noted, however, that this is inherently conservative, because false negatives mean that some episodes of actual manipulation are excluded from the damages calculation.

118. The restrictive criteria for identify manipulative episodes in the methodology described *supra*—including the fact that the process is based on express statements of intent—are explicitly intended to, and will have the effect of, severely circumscribing false positives.

119. There is typically a trade-off between false positives and false negatives: reducing the frequency of false positives usually increases the frequency of false negatives, and that is the case here. The rigorous criteria described *supra* mean that actual manipulative episodes will be excluded from the damages analysis. There are multiple reasons for this.

120. First, a trader can bang the fix without communicating his or her intent *via* a medium available to the Plaintiffs.

121. Second, some communications that indicate manipulative intent are insufficiently detailed (in terms of maturity and direction most notably) to permit application of the immediate impact and permanent impact screens, and hence are excluded.

122. Third, the impact screens are subject to false negatives. For example, a rate may move down even when a trader attempts to move it up by banging-the-fix due to other factors (including, *inter alia*, non-manipulative trades in the opposite direction by others, or the revelation of information): here, the Reference Rate would be higher than it

would have been but for the manipulative trading, but the impact screens exclude it from consideration nonetheless.[20] Put another way, an attempt to manipulate an ISDAfix rate up may have succeeded in *slowing* the *downward* trend caused by other factors. In such an instance, rates would have been artificially "high," because they would have been *lower* but for the manipulation. However, under the tests as described above—which are based on absolute movements within the measurement windows—a successful attempt to slow the descent of rates would be rejected as a (false) negative.

123. Fourth, manipulations could have moved control rates because of linkages between markets, thereby resulting in no movement in the difference between the swap rate on ICAP and the control rate. For example, a manipulation that involved the sale of large quantities of Eurodollar futures would have raised a control rate as well as the Reference Rate, thereby obscuring the impact of the manipulation. Relatedly, arbitrage linkages and information flows between related markets (e.g., between the swaps market and the Eurodollar futures market, or the swaps market and the Treasury futures market) would tend to reduce the measured impact of manipulation on the difference between a swaps rate and control rates, thereby increasing the likelihood that a particular suspected manipulation would survive the impact filters. (This would also tend to reduce the measured impact of the manipulation.)

124. Thus, the methodology is conservative in many ways. To be included in a damages calculation, a particular bang-the-fix episode must pass rigorous documentary

[20] This can occur even if control rates are used, because the difference between an unmanipulated swap rate and a control rate varies due to various factors. For instance, a large non-manipulative sell trade in Treasury futures could drive up the control rate around 11:00AM, resulting in a decline in the difference between the swap rate on ICAP and the control rate.

and rate impact filters. These filters are much more likely to exclude from damages calculations actual instance of manipulation, than they are to include non-manipulative episodes.

125. Furthermore, if the trier of fact determines that any event that Plaintiffs identify and which passes the impact filter was not actually a manipulation, this event can be excluded from the calculation of the artificiality ribbon. Therefore, the methodology will produce an artificiality ribbon that includes only events which qualify under the Plaintiffs' rigorous criteria and are accepted by the trier of fact.

126. It should be noted that the data support the reliability of the method for identifying manipulations. In Mr. Farrell's report there are 47 instances where communications provide strong evidence of manipulation. If the documentary evidence were not a reliable basis for identifying manipulations, then the allegedly manipulated rate on a day identified as a manipulation date would be equally likely to move in the direction of the alleged manipulation or in the opposite direction. That is, if the documentary evidence did not contain information relevant in determining manipulation dates, the identifications used to construct the ribbon would be equivalent to a coin flip, and given 47 instances, one would expect to observe 23 or 24 cases in which the rate moves in the direction implied by the documentary evidence. However, if the documentary evidence does provide information relevant in determining manipulation dates, the allegedly manipulated rate will move in the direction of the manipulation identified in the documents more than 50 percent of the time.

127. This is indeed the case. Under Methodology 1 (no control variable), in the illustrative sample of 47 bang-the-fix episodes, the allegedly manipulated rate moves in

the direction of the manipulation inferred from the documents 78.7 percent of the time. The likelihood of observing this rate of correspondence between the actual rate movement and the movement predicted based on the documentary evidence under the null hypothesis that the documentary evidence does not provide information on manipulation (i.e., it is no better than a coin flip) is .01 percent.

128. Under Methodology 2 (control variable), the allegedly manipulated rate moves in the direction of the manipulation inferred from the documents 70.2 percent of the time. The likelihood of observing this rate of correspondence between the actual rate movement and the movement predicted based on the documentary evidence under the null hypothesis that the documentary evidence does not provide information on manipulation (i.e., it is no better than a coin flip) is .3 percent. Thus, it is possible to reject the null hypothesis that the documentary evidence does not provide evidence of manipulation at confidence levels far higher than the conventional 1 percent and 5 percent levels.

129. Under the preferred Combined Methodology, the allegedly manipulated rate moves in the direction implied by the documents 83.0 percent of the time. The probability of observing this rate of correspondence between the actual rate movement and the movement predicted based on the documentary evidence under the null hypothesis that the documentary evidence does not provide information on manipulation is .01 percent. Thus, it is possible to reject the null hypothesis that the documentary evidence does not provide evidence of manipulation at confidence levels far higher than the conventional 1 percent and 5 percent levels.

130. In sum, the methodology I intend to employ (a) is actually favorable to Defendants, and (b) reliably identifies manipulations.

**H. Potential Enhancements of the Methodology**

131. The methodology described above measures "temporary" and "permanent" impact of attempts to manipulate using movements in the midpoint between bids and asks for swaps. This methodology is appropriate because, among other things, I understand the "time stamps" for interest rate swaps do not necessarily reflect the exact minute and second the transaction was actually consummated and reflected in what would become the Reference Rate. For Treasuries transactions, however, I understand there is a dataset of accurately "time stamped" data: namely, that of BrokerTec. Because Plaintiffs allege that Defendants utilized Treasuries trades as another tool used to drive rates to artificial levels (due to the relationship between Treasuries yields and USD swap rates), an analysis of this data would provide yet another way to capture *even more* artificiality associated with any evidence gathered by Plaintiffs regarding a particular attempt to manipulate ISDAfix rates on a given day

132. I understand that ICAP administers the Treasuries trading platform called BrokerTec, which was used as part of the process of creating Reference Rates. BrokerTec produces transaction and order flow (i.e., bids, offers, modifications, and cancellations) data that is time stamped to the second, and which is sequenced exactly (even for actions that occur within the same second). This data can be analyzed using the methods described at ¶¶52-55 *supra* to estimate the price impact of Treasury trades, and how this impact varies with trade quantity. The price impact coefficients estimated from this data can be utilized to quantify temporary and permanent impacts of manipulative

episodes that (a) Plaintiffs' analysis of the communications indicates may have been carried out in part through trading Treasuries on BrokerTec, and (b) Defendants' trade data indicates that they in fact traded Treasuries sometime prior to 11:00AM on the day of the alleged manipulation.

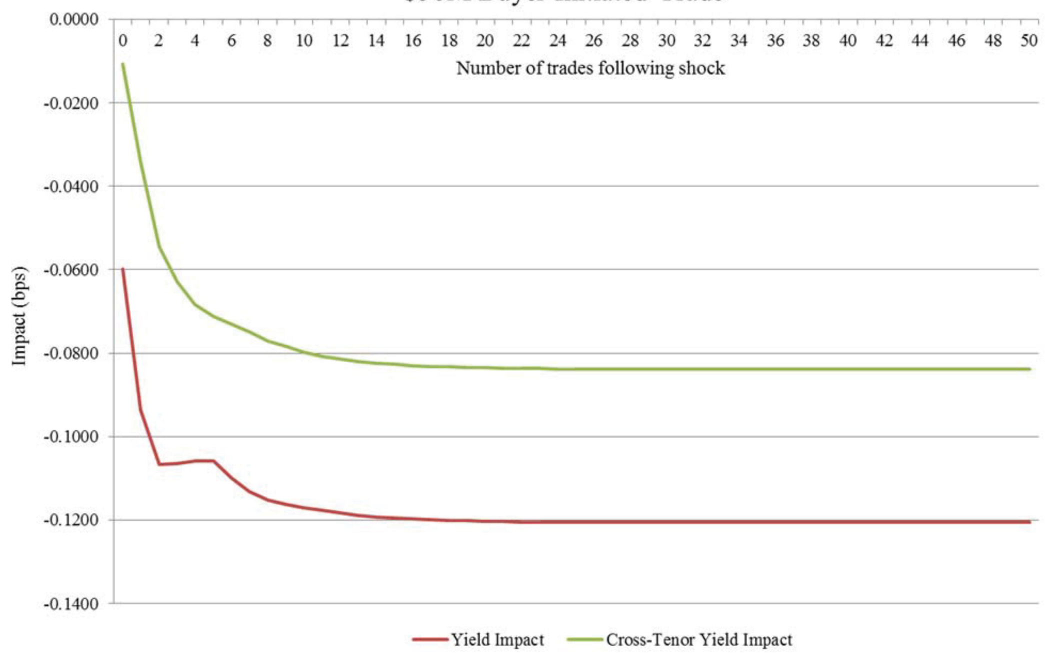
133. As noted at ¶57 *supra* at least one study undertaken by reputable scholars under the auspices of the Federal Reserve Bank of New York uses the VAR methodology to document that trades on BrokerTec (a) have permanent impacts on prices, and (b) have impact that increases with trade size. I have implemented a VAR analysis on some BrokerTec data from the Class Period to demonstrate that I can implement this analysis in order to quantify price impact.

134. Specifically, using BrokerTec data for the ten-year and five-year Treasury notes on the manipulation dates from the representative sample of 41 dates,[21] the empirical analysis demonstrates that (a) trades in the ten-year Treasury cause permanent movements in its yield, (b) trades in the ten-year Treasury cause permanent movements in the yield of the five-year Treasury, (c) trades in the five-year Treasury cause permanent movements in its yield, (d) trades in the five-year Treasury cause permanent movements in the yield of the ten-year Treasury, (e) bids and offers in the five- and ten-year Treasuries move both rates, with a somewhat smaller impact than for trades, (e) these movements are permanent, and (f) over 99 percent of the ultimate impact of a trade occurs within 20 trades. Given an average trade rate of around 18 trades per minute, this means that the full permanent impact typically occurs within approximately one minute of a trade.

[21] The illustrative sample of 47 bang-the-fix episodes occurred on 41 unique dates.

135. Figure 3 illustrates the Impulse Response Function for trades on the ten-year Treasury. The red line illustrates the average impact of a $50 million purchase in the ten-year on the yield of the ten-year. The green line illustrates the average impact of a $50 million purchase in the ten-year on the yield of the five-year. Since prices and yields move in the opposite direction, a negative sign means that purchases drive down yields, and hence drive up prices.

Figure 3
Impulse Response Function
$50M Buyer-Initiated Trade




**Sources:** ICAP, Bloomberg
**Note:** The horizontal axis refers to the number of trades following the shock, and the corresponding quote refers to the change in the quoted yields after the trade.

136. Note that both curves flatten out and remain relatively constant after approximately 20 trades. This indicates that yields respond rapidly to trades. In the data, there are approximately 18 trades per minute, meaning that the permanent impact occurs within approximately a minute of a trade. Further, the level of yield change corresponding to the flat range is a measure of the permanent impact of the trade. The

figure illustrates that even in one of the most liquid markets in the world, trades impact prices, and indeed have permanent effects.

137. For those episodes in which the evidence shows that a Defendant traded Treasuries on BrokerTec pursuant to an attempt to bang the fix on a particular day, the yield impact impulse response functions estimated using the VAR methodology can be used to estimate price impact for this manipulation.

138. Similarly, for those episodes in which the evidence shows that a Defendant submitted bids or offers Treasuries on BrokerTec pursuant to an attempt to bang the fix on a particular day, the price impacts (appropriately converted to yields) estimated using the VAR methodology can be used to estimate price impact for this manipulation.

139. Specifically, the price impact on the Reference Rate (which reflects price impact until 11:00AM) of trades is measured by multiplying the Defendant's net trades (purchases minus sales) on BrokerTec in the maturity targeted in the manipulation over some time period prior to 11:00AM by the trade impulse response function value corresponding to 11:00AM estimated from the VAR for that maturity. Multiplying the net trades prior to 11:00AM by the value at which the impulse response function flattens out measures the permanent impact. The permanent impact is added to the artificiality ribbon to determine cumulative artificiality through this manipulative episode.

140. Similarly, price impact of quotes on the Reference Rate (which reflects price impact until 11:00AM) is measured by multiplying the Defendant's bids and offers on BrokerTec in the maturity targeted in the manipulation over some time period prior to 11:00AM by the bid or offer impulse response function value corresponding to 11:00AM

estimated from the VAR for that maturity. Multiplying the bids and offers prior to 11:00AM by the value at which the impulse response function flattens out measures the permanent impact. Converting these price impacts to yield impacts (based on the exact maturity and coupon of the Treasury security used in the manipulation) produces a measure of the temporary and permanent impacts. The permanent impact is added to the artificiality ribbon to determine cumulative artificiality through this manipulative episode.

141. Note that this method uses impulse response functions estimated from BrokerTec data and the manipulating Defendant's trades to estimate price impact from a Treasury-based manipulation, rather than the actual price movements in Treasury yields around 11:00AM on the manipulation date in question. This approach offers some advantages.

142. Most notably, it utilizes data from a large number of trades on BrokerTec to quantify how trades affect prices over different time horizons. This permits estimates of the effects of a Defendant's manipulative trades in Treasuries that are not affected by confounding factors, such as non-manipulative trades and the arrival of public information that can cause observed prices to move in the opposite direction from the manipulation. Thus, this method reduces the frequency of false negatives, and also permits a more accurate quantification of artificiality.

143. Use of the estimated impulse response functions from a large number of trades to estimate the impact of a particular manipulative trade is justified by the fact that the BrokerTec platform is anonymous, and hence the identity and motives of traders are unknown for all trades. In this trading environment manipulative trades are

indistinguishable from non-manipulative ones: indeed, the manipulator exploits this very fact.[22] Therefore, the impact of a manipulative trade *per se* should be the same as the impact of a similarly-sized trade estimated from a large number of trades.

144. The fact that some manipulations were executed by trading Treasury securities also opens another possible route to identify bang-the-fix episodes. Specifically, a Defendant intending to manipulate the Reference Rate could do so by trading Treasuries, and moreover, could do so independently without communicating with ICAP or another trader. This creates the possibility of identifying manipulations by examining Defendants' trades on BrokerTec for evidence of large volumes of Treasury trades in a period ending at 11:00AM. Work in this area is ongoing.

145. There is a justification for applying the VAR-impulse response function-based measure of price impact to all episodes of manipulation identified by Plaintiffs based on documentary evidence in order to create an artificiality ribbon that is (a) conservative, and (b) is not affected by confounding factors such as non-manipulative trades or the arrival of public information. The reasoning is as follows. Manipulators want to maximize price impact for a given expenditure of "ammunition" (in the argot of their communications). Therefore, they would have traded Treasuries when they thought this would have the greatest impact, and swaps when they thought the impact would be greater there. Thus, price impact estimated from BrokerTec data provides a lower bound on the price impact of manipulative trades generally. The fact that it is a lower bound means that the methodology is conservative. The fact that it is estimated from data involving large numbers of trades means that it is not affected by confounding factors.

[22] See Section IV.C *supra*, and note 14 *supra*.

146. In a perfect world, it would be possible to employ this methodology for swap transactions as well. Unfortunately, the nature of the swaps data precludes for swaps implementation of the methodology that is feasible for Treasury trades on BrokerTec. In particular, the reporting of swap transactions is delayed, and recorded times do not correspond to the actual time of execution. Furthermore, given the way that ICAP recorded swaps transactions, recorded times do not even permit the determination of the actual sequence of trades.

147. The limitations of swap data, and the fact that Defendants executed some manipulations by trading swaps, necessitate utilization of the basic methodology described at Sections V.A-F *supra*. In this regard, it is crucial to note that the basic methodology discussed in sections V.A-F *supra* does ***not*** depend on precise time stamping in order to estimate temporary or permanent price impacts. Manipulation of the fix required trading prior to 11:00AM. Therefore, rate movements over an interval ending at 11:00AM is sufficient to determine the immediate impact of manipulative trading during episodes identified by Plaintiffs: the timing of communications that Mr. Farrell will utilize to identify these manipulations can be used to bound the beginning of the time interval. Furthermore, since manipulative trades would necessarily have occurred prior to 11:00AM, bang-the-fix trades would *not* have taken place in the minutes after 11:00AM, meaning that there are no relevant trades in the post-11:00AM period used to estimate the permanent impact, so the time stamping issue is a red herring for this period. Thus, it is possible to quantify transitory and permanent manipulative rate impacts using the standard methodology even in the absence of accurately time stamped swap transaction data: the methodology depends only on the facts that manipulative

trades took place in a period ending at 11:00AM, and that no bang-the-fix trades could have taken place afterwards.

148. However, for some manipulations this basic methodology can be enhanced by utilizing price impacts estimated from BrokerTec data. Crucially, this enhancement can be applied systematically on a class-wide basis in episodes in which there is evidence from the documentary record or Defendants' trading records that manipulations were consummated in part through trading in volume on BrokerTec.

## VI. Application of the Artificiality Ribbon to Determine Damages on Individual Transactions

### A. Methodology Overview

149. Section V *supra* describes the methodology for creating an artificiality ribbon that, when combined with the actual rates for a given day, implies a set of "but-for" rates for every day in the Class Period. What follows describes how to utilize such a ribbon to determine the damage on any particular transaction.

150. For any instrument the damages methodology has two basic elements, corresponding to the immediate and permanent impacts of bang-the-fix trading.

151. The first element determines the damages arising from the settlement of instruments or the determination of cash flows that are tied directly to a manipulated ISDAfix rate. An example of this would be a cash-settled swaption position held by a Class Member that settled against a manipulated ISDAfix rate (where the existence of a manipulation, and the impact thereof on rates, will be determined using the methodology set out *supra*). I refer to these as "cashflow damages."

152. The second element determines damages arising from the purchase and sale of instruments during the Class Period, including on days on which no bang-the-fix trading has yet been identified in discovery. Recall from the discussion at ¶¶113-114 *supra* that since bang-the-fix trading can cause permanent changes in rates, it is likely that on most days of the Class Period (and perhaps all days subsequent to the first instance of a bang-the-fix manipulation) there will be a non-zero difference between the market swap rate and the but-for swap rate: only in the event that as of a given date prior bang-the-fix episodes cumulatively had equal and offsetting impacts would this difference equal zero. Where these do not sum to zero, such differences would have damaged at least some Class Members. For example, consider a Class Member who sold a vanilla interest rate swap on a day when as a result of previous bang-the-fix manipulations, the actual swap rate was less than the but-for rate. This Class Member would have suffered harm equal to the present value of the difference between the actual and but-for rates. I refer to these as "price damages."

153. Below I provide a detailed description of the damage calculation for each of these two elements of damage for exemplary transactions. Using similar industry-standard valuation techniques, the artificiality ribbon can be used to determine the impact of Defendants' manipulations for any interest rate derivative.

**B. Use of the Industry-Standard Formula to Re-Value a Swaption Using the Artificiality Ribbon**

154. As one example of how the "ribbon" can be applied to calculate damages on transactions that could have included both price damages and cashflow damages (because the contract was settled against a manipulated ISDAfix rate), consider a cash-settled swaption.

155. A swaption is an option that grants its owner the right but not the obligation to enter into an interest rate swap on a specified future date, in exchange for an option premium. There are two different kinds of swaptions; a payer swaption and a receiver swaption: (a) a payer swaption affords the purchaser the right, but not the obligation, to enter into an interest rate swap contract and pay a fixed rate of interest; while (b) a receiver swaption affords the purchaser the right, but not the obligation, to enter into an interest rate swap contract and receive a fixed rate of interest. The fixed rate of interest specified in the contract is called the "strike price" or simply "the strike."

156. A swaption purchaser and seller will agree jointly at the outset of a trade the convention that determines when a swaption may be exercised. The main conventions are:

- American – the option right can be exercised at any time up to and including the expiry date of the option.
- European – the option right can be exercised only on the expiry date.
- Bermudan – the option right can be exercised on certain predetermined dates up to and including the expiry date.

157. If a swaption is in the money[23] on the option expiry date, the swaption purchaser will likely exercise his or her option. If the swaption is cash settled the swaption purchaser will expect to receive a cash amount equal to the present value of the swap at the point of exercise from the swaption seller. In the case of a physically settled swaption, upon exercise the swaption purchaser will enter into an actual interest rate swap with the swaption seller.

[23] In the money means that the strike rate is more favorable than the market rate (i.e., higher than the market if receiving fixed and lower than the market if paying fixed). Out of the money means that the strike rate is less favorable than the market rate (i.e., higher than the market if paying fixed and lower than the market if receiving fixed). At the money means that the strike rate is identical to the market rate.

158. One issue that arises with swaptions is whether Class Members would have bought or sold these contracts with the same strike prices as indicated in the transaction records, even if the swap rates had equaled the but-for rates at the times they transacted. Without expressing any opinion as to the legal propriety of taking such additional movements in the but-for rate into account, I note that swaptions are commonly purchased or sold on a Delta basis. That is, a Class Member buying or selling a swaption would often specify a desired Delta (e.g., .5), and a Defendant would quote a price for a swaption with a strike price that produces the desired Delta. This strike price will vary with the market swap rate. For example, for a payer swaption, the strike price for a given Delta is an increasing function of the relevant swap rate.

159. The most plausible assumption that can be made, and applied on a class-wide basis, that addresses this issue is that all Class Members initially purchased or sold swaptions on a Delta basis. This assumption is plausible because it reflects market realities. Those trading swaptions that are hedging an interest rate exposure, or are taking a position on volatility, or are hedging volatility risk, typically care about the moneyness of the option, i.e., how much the option strike price differs from the current rate on the instrument underlying the swaption (e.g., the ten-year swap rate).

160. Given this assumption, the damage calculation proceeds as follows. First, the Delta of the initial transaction is determined using the relevant market swap rate, the strike reported in the transaction record, the time to maturity implied by the transaction record, the appropriate risk free interest rate, and the implied volatility determined from the Black swaption model using the market swap rate, the contractual features of the swaption, and the transaction price reported in the record. Second, using the Black

swaption model and the implied volatility, the "but-for strike price" that generates the same Delta is calculated. Third, one component of the damage is the difference between the premium of the swaption and the but-for value of the swaption calculated using the but-for swap rate and the but-for strike. Fourth, the transaction record will be searched for an offsetting transaction between the same counterparty and Defendant that matches all contractual terms (expiration date, notional amount, option type, strike price). If such a transaction exists, the value of the swaption will be calculated using the but-for strike and the but-for swap rate, and the difference between this value and the transaction price will represent the second damages component. Fifth, if no such offsetting transaction is found, I will assume the option was held to expiry. In this case, the second damage component will be determined based on the difference between the actual proceeds from exercise (which may be zero) and the proceeds from exercise implied by the difference between the but-for swap rate at expiry and the but-for strike.[24]

[24] An alternative assumption that can be made is that Class Members trading swaptions would have bought/sold options with the same strike prices even if swap rates had equaled the but-for rates, rather than the market rates distorted by past manipulations. Under this assumption, there are also two components to damages on swaptions trades: the part attributable to distortions in the premium at the time the Class Member bought/sold the option, and the part attributable to distortions in premium or exercise proceeds at the time the transaction was terminated. The process for determining the damage on this transaction will proceed as follows. First, for each initial swaption transaction, the first damage component will be based on the difference between the actual premium for the option and the premium produced by the Black swaption model using the contractual terms for the option (including the strike stated in the transaction record), the implied volatility calculated from the premium indicated in the transaction record and the market swap rate, and the but-for swap rate. Second, the transaction record will be searched for an offsetting transaction between the same counterparty and Defendant that matches all contractual terms (expiration date, notional amount, option type, strike price). If such a transaction exists, the value of the swaption will be calculated using the contractual strike and the but-for swap rate, and the difference between this value and the transaction price will represent the second damages component. Third, if no such offsetting transaction is found, I will assume the option was

161. ***Price damages***. For both cash settled and physically settled swaptions, the price of the swaption depends on a variety of variables, one of which is market expectations of future swap rates relative to the strike of the swaption. The difference between actual and but-for forward swap rates therefore impacts the price of a swaption, i.e., the amount paid or received on the trade date or the unwind date. Price damages are calculated as the difference between the price of the swaption based on actual market data and the price of the swaption based on but-for market data.

162. For illustration purposes, I focus on cash European swaptions which I value using the standard Black-76 model.[25] This model is applied by many market participants as well as academics.

163. The Black-76 model is well documented in academic literature, relatively straightforward to implement and does not require complex calibration as is the case for other models. It is also a closed-form[26] model which means its output is the result of an (albeit complex) mathematical equation.[27]

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held to expiry. In this case, the second damage component will be determined based on the difference between the actual proceeds from exercise (which may be zero) and the proceeds from exercise implied by the difference between the but-for swap rate at expiry, and the contractual strike. This assumption is less reflective of market practices than my preferred assumption that market participants negotiated the strike to achieve a particular Delta (or in fact negotiated a particular Delta, which then mechanically produced a strike price through the application of a standard valuation formula such as the Black Model). I therefore anticipate that I will employ the preferred assumption for the purpose of calculating class-wide damages at trial.

[25] Black, F., The Pricing of Commodity Contracts, 3 Journal of Financial Economics (1976) 167.

[26] Closed-form means that the model can be denoted as a mathematical expression that can be evaluated in a finite number of operations

[27] For more details, see Damiano Brigo and Fabio Mercurio, Interest Rate Models--Theory and Practice (2006). Notation is taken from Brigo-Mercurio.

164. Let $T_{\alpha+1}, \dots, T_\beta$ describe the coupon dates and $T_\alpha, \dots, T_{\beta-1}$ the resetting dates of the underlying swap. Then the value $V^{PaySwaption}(t_0)$ of a payer swaption is given by

$$V^{PaySwaption}(t_0) = N \cdot Bl\left(K, S_{\alpha,\beta}(t_0), \sigma_{\alpha,\beta}\sqrt{T_\alpha - t_0}, 1\right) \sum_{I=\alpha+1}^{\beta} D_{T_i} \tau(T_{i-1}, T_i),$$

where $S_{\alpha,\beta}(t_0)$ is the forward swap rate for the above coupon dates at time $t_0$, which under Black is log-normally distributed with $\sigma_{\alpha,\beta}$ as volatility and N is the notional of the underlying swap. Similarly, the value $V^{RecSwaption}(t_0)$ of a receiver swaption is given by

$$V^{RecSwaption}(t_0) = N \cdot Bl\left(K, S_{\alpha,\beta}(t_0), \sigma_{\alpha,\beta}\sqrt{T_\alpha - t_0}, -1\right) \sum_{\alpha+1}^{\beta} D_{T_i} \tau(T_{i-1}, T_i),$$

$Bl$ is standard notation indicating the Black formula.

165. All this means simply this: there is an industry-standard formula that can be used to "re-price" or "re-value" swaptions, using the but-for rate in order to determine the effect of bang-the-fix manipulations.

166. ***Cashflow damages.*** For cash settled swaptions, ISDAfix manipulation may give rise to cashflow damages on the exercise date in the following three scenarios: (1) the swaption is in the money ("ITM") using both actual and but-for pricing data; (2) the swaption is out of the money ("OTM") but would be in the money in the absence of manipulation; or (3) the swaption is ITM on the exercise date but would have been OTM in the absence of manipulation.

167. It should be noted that because these contracts by definition are tied to ISDAfix rates, which were determined (due to rubberstamping) by the Reference Rates,

cash flow calculations should reflect the full impact of bang-the-fix trading on that date, as well as the cumulative permanent impact of previous manipulations. That is, the but-for rate should incorporate both the temporary and permanent impacts of the manipulation on the settlement date.

168. In the first scenario, exercise date cashflow damages can be estimated by valuing the underlying swap on the exercise date using both actual and but-for ISDAfix rates and calculating the difference between these two valuations. In the second and third scenarios, the swaption exercise decision would likely have been different had but-for ISDAfix rates prevailed on the exercise date. Hence, cashflow damages are likely to equal the full amount of the present value of the underlying swap on the exercise date. Section VI.C *infra* discusses the application of the artificiality ribbon in calculating the present value of swaps.

169. The table below summarizes the various scenarios for damages on the swaption exercise date.

**Table 2**

| **Swaption value on expiry date** | | **Outcome** |
|---|---|---|
| **Actual** | **But-for** | |
| ITM | ITM | Possible damages |
| ITM | OTM | Possible damages |
| OTM | ITM | Possible damages |
| OTM | OTM | No exercise date damages |

170. Unlike with cash settled swaptions, potential cashflow damage for physically settled swaptions do not arise on the exercise date but accrue over the life of the underlying swap. Cashflow damages can therefore be estimated as the sum of the differences between the actual cashflows paid/received over the life of the underlying

swap, and cashflows calculated using a but-for fixed rate based on but-for market data as of the trade date.

171. To illustrate a swaption cashflow damages estimate, I consider a the following swaption entered into by Named Plaintiff [redacted]:[28]

**Table 3**

| **Swaption Transactional Data** | |
|---|---|
| Trade Date | [redacted] |
| Notional Traded | |
| Strike (percent) | |
| Trade Direction | |
| Exercise Date | |
| Option Type | |
| Underlying Swap Tenor | |
| Damages Quantum on Expiry Date | |

172. Based on the sample artificiality ribbon discussed at ¶¶111-116 *supra*, the cashflow damages on this transaction are [redacted].

173. To illustrate a price damages estimate, I consider the following transaction between the [redacted] and Defendant Citibank:

[28] As the terms of this swaption are being used only for purposes of illustrating the calculation methodology, I simply presume that that it was cash settled after expiring in the money.

**Table 4**

| Swaption Transactional Data | |
|---|---|
| Trade Date | [redacted] |
| Notional Traded | |
| Strike (percent) | |
| Trade Direction | |
| Expiry Date | |
| Option Type | |
| Underlying Swap Tenor | |
| Damages Quantum on Trade Date | |

The price damages on the trade date are approximately [redacted].

### C. Use of an Industry-Standard Formula to Re-Value a Vanilla Swap Using the Artificiality Ribbon

174. A vanilla interest rate swap is an agreement between two counterparties in which one stream of future interest payments is exchanged for another based on a specified principal amount. Vanilla swaps usually involve the exchange of a fixed interest rate for a floating rate (typically LIBOR plus a margin).

175. ***Price damages***. Consider the sale of a five-year swap on a day when the market swap rate (which includes the impact of previous bang-the-fix manipulations) was below the five-year but-for rate. The purchaser was damaged by an amount equal to the present value of the difference between the actual and but-for rates because it received cash flows based on the artificially low market swap rate, rather than the higher but-for rate. Given the terms of the swap, this calculation can be made using standard valuation formula and available market pricing data.[29]

[29] Present value factors are derived from the term structure of swap rates. In making a calculation of discount factors necessary to determine the "price value of a basis point"

176. Price damages for vanilla swaps arise from the difference between the price of the trade based on actual market data and the price based on but-for market data. The price of an IRS is determined as:[30]

177. Let $T_{\alpha+1}, \dots, T_\beta$ describe the coupon dates and $T_\alpha, \dots, T_{\beta-1}$ the resetting dates. The value of the fix leg in $t_0$ is then given by

$$V^{fix}(t_0) = \sum_{i=\alpha+1}^{\beta} D_{T_i}\tau(T_{i-1}, T_i)C,$$

and the value of the floating leg is given by

$$V^{float}(t_0) = \mathrm{N}\ \mathrm{m}\left[D_{T_\alpha} - D_{T_\beta}\right] + \mathrm{N}\sum_{i=\alpha+1}^{\beta} D_{T_i}\tau(T_{i-1}, T_i)s$$

178. ***Cashflow damages***. Cashflow damages for a vanilla interest rate swap are zero. The fixed rate of the swap is determined at trade inception and the floating payment going forward is determined by LIBOR rates rather than ISDAfix rates.

179. To illustrate the calculation of damages, I consider the following IRS traded by the [redacted] with Defendant Morgan Stanley:

(or "dollar value of a basis point") used to value a vanilla swap, and other swap-related instruments (e.g., a swaption) it is appropriate to use the swaps term structure implied by the but-for swap rates.

[30] For more details and notations, see Brigo and Mercurio *supra* note 27 at 13. The equations in the text utilize the notation from Brigo-Mercurio.

**Table 5**

| Swap Transactional Data | |
|---|---|
| Trade Date | [redacted] |
| Notional Traded | |
| Trade Direction | |
| Tenor | |
| Artificiality on Trade Date | |

The price damages on this transaction on the trade date are approximately [redacted]

**D. Implementation Details Related to the Data Produced by Defendants**

180. As noted *supra*, a Class Member could have suffered damages on the purchase or sale of instruments with values that depended on manipulated swap rates. The transaction data produced by Defendants will be utilized to identify each such potentially damaged transaction during the Class Period.

181. Limitations of the available data introduce another source of ambiguity that necessitates the calculation of a range of damages on some transactions. Specifically, the transaction data Defendants have produced does not contain (reliable) information on the time of a transaction. This creates ambiguity on days when a bang-the-fix manipulation occurred, because there are three potential but-for prices on such days: (a) the but-for price prior to 11:00AM, which reflects the cumulative permanent effects of manipulations on prior days; (b) the but-for price at 11:00AM, which reflects both the transitory and permanent impacts of the bang-the-fix manipulation that occurred on this day; and (c) the but-for price subsequent to 11:00AM, which reflects the cumulative effects of manipulations including the manipulation on this day.

182. For the purpose of calculating damages for presentation at trial, I anticipate that I will utilize the most conservative estimate of damages on a particular transaction. That is, for each transaction subject to the ambiguity, I will calculate damages under alternatives (a)-(c) above. I will use the smallest of the three damage figures to measure the damage on this particular transaction.

183. It should be noted that this timing issue affects only a small subset of the total transactions at issue in this case. In particular, it only affects transactions entered into or offset on days with a new bang-the-fix episode; on all other days, the amount of artificiality is constant. It should also be noted that this timing issue does not affect transactions *settled against* ISDAfix rates on a manipulation date. For example, the damage on a cash-settled swaption maturing on a manipulation date depends on the artificiality at 11:00AM: the methodology produces an artificiality number at this exact time on a manipulation day.

## VII. Application of the Damages Model Across Multiple Transactions

### A. Overview

184. As already noted, Section V *supra* describes how to quantify the incremental artificiality created by particular acts of "banging the fix." Section VI *supra* then describes how to use that ribbon of artificiality to measure damages as to virtually any instrument, on any given day during the class period. This Section discusses generally how that process can be applied to any number of transactions deemed relevant for any particular purpose.

**B. The Ability to Determine a Class-Wide Damages Figure**

185. Because the artificiality "ribbon" is the same for all Class Members, and the industry-standard valuation techniques like those discussed above are the same for all Class Members, it is possible to scale up the above examples to a transactional dataset of virtually any size.

186. Here, for example, Defendants have produced much transactional data, revealing their transactions with Class Members during the Class Period. The above valuation models, or similarly standard models, can be used to determine the actual and "but for" value for such transactions. After making adjustments such as removing from the dataset transactions between two Defendants (which are excluded from the Class), an estimate of class-wide damages can be obtained by simply summing up the individual damages calculated when applying the above techniques to each individual transaction.

187. Similarly, if it is necessary to determine the damages arising out of a *particular* Defendants' transactions, one could do the same summation, but only look within that particular Defendants' transactional production.

188. I note again that it is of course possible that a Class Member actually benefited from artificiality on some transactions. It is also possible that this Class Member was damaged by artificiality on other transactions. Based on discussions with Class Counsel, it is my understanding that it may not be necessary to subtract the gains from the losses attributable to manipulation across all transactions entered into by that Class Member in order to determine class-wide damages.

189. However, if the Court finds that it is necessary to deduct gains from losses to determine each Class Member's net damages, it will be possible to do so for presentation at trial.

190. For purposes of calculating a Class-wide damages estimate, this would simply involve including transactions in the above summation process regardless of whether they benefitted from or were harmed by the effects of the artificiality ribbon. Similarly, adding up all the Defendant-Class Member transactions within one Defendants' production would yield a "net" damages figure for all transactions done in privity with that particular Defendant.

### C. The Ability to Determine Each Class Member's Damages

191. The methodology just described for calculating damages on a class-wide basis at trial is easily adapted to calculating damages incurred by each Class Member.

192. As an initial matter, many individualized calculations can be performed with the data produced by Defendants. Many Defendants have already produced counterparty-identifying information, and I understand negotiations are still underway for additional such data.

193. Where sufficient identifying information is provided, this would allow Class Counsel to provide an estimate of damages—even on a "net" basis—even down to the granular level of a particular Class Member, using the same methodologies above. This is likely true even though there may be complicating factors, such as that transaction records produced by one Defendant refers to a Class Member as "yx" whereas transaction records produced by another Defendant that same Class Member as "yz," or that Defendants are relying on privacy laws to withhold from Class Counsel themselves the exact identity of a subset of Class Members (using instead "ID numbers" or the like). Such issues are routine in cases like this, and can be worked through with Defendants as part of the notice process.

194. Further, I note that for purposes of claims administration, such analysis can of course be supplemented with an additional set of data. In lieu of transaction data produced by Defendants, Class Members can provide records of their transactions. The valuation methodology described *supra* can be applied to these transaction records to determine the damage attributable to each individual transaction. These can be added across all of a Class Member's transactions to determine that Class Member's total damages. This method of adding a given Class Member's gains and losses attributable to manipulative price impact across all of that Class Member's transactions ensures that damages are netted across Defendants, if such netting is determined to be required.

## VIII. Impact on Class Members

### A. Daily Rubberstamping by Defendants Means Every Day Was Artificial

195. I understand that Dr. Williams is providing an opinion indicating that the panel banks were obligated to respond each day to the ISDAfix "poll" with what *that specific bank* would be willing to [redacted].[31]

196. I understand Dr. Williams has further concluded that the panel banks did not comply with ISDA's requirements for their poll submissions. Instead, Dr. Williams concludes that the Defendant Banks rubberstamped the reference rate in their submissions almost every day over the period of 2006 through late 2012. He also concludes that because such rubberstamping occurred, their common poll submissions became the final ISDAfix rate almost every day prior to late 2012.

[31] *See generally, e.g.*, ISDAFIX-0030203 at 3 (10/24/2005 executed BNPP USD ISDAfix contribution agreement).

197. In the most basic sense, then, rates—and thus, Class Members—were impacted by the allegedly collusive scheme on a *daily* basis. *Every* time rubberstamping occurred, rates were being set at an artificial level. All Class Members were thus continually transacting in an artificial market, because of the alleged conspiracy.

**B. Application of the Artificiality Ribbon to Named Plaintiffs**

198. Despite the above, Class Counsel has asked me to analyze whether the named Plaintiffs in this case were not just impacted in that general, universal sense, but also whether they had at least one transaction that can be shown to have been, in addition, negatively impacted even when viewed from the much more limited window of the "artificiality ribbon" available at this time.[32]

199. *For the Alaska Electrical Pension Fund*, applying the artificiality ribbon in its current form to its transactional data finds [redacted].

200. *For the Genesee County Employees' Retirement System*, applying the artificiality ribbon in its current form to its transactional data similarly finds [redacted].

201. *For the County of Montgomery, Pennsylvania*, that Plaintiff had a non-vanilla swap transaction, with a complex payout formula that incorporated various ISDAfix rates at many points during the life. A full modeling of the transaction is ongoing, but I have confirmed that [redacted].

[32] I am using the phrase "negatively impacted" in the mathematical sense; I am not taking any position with respect to what is necessary or sufficient for any legal purpose.

202. *For the County of Washington, Pennsylvania*, I have been informed by Counsel that a pre-existing swaption was amended within the Class Period, such that the underlying swap—if the option held by JP Morgan was exercised—would have been directly linked to ISDAfix rates. At the time of the amendment, the County paid JP Morgan a fee. Later, as the swaption was deep in the money, it was terminated, with the County paying another fee to JP Morgan. The same artificiality ribbon discussed herein, common to all class members, can be applied to this transaction through the use of similar models as detailed herein for the vanilla swaps and swaptions. This is because, as the underlying swap in this case would have been ISDAfix-linked, the conspiracy's impact on these events would be similar to those explained herein for vanilla swaps and swaptions.

203. *For the City of New Britain, Connecticut*, applying the artificiality ribbon in its current form to its transactional data finds that [redacted].

204. *For the Pennsylvania Turnpike Commission*, that Plaintiff had a non-vanilla swap transaction, with a complex payout formula that incorporated various ISDAfix rates at many points during the life. A full modeling of the transaction is ongoing, but I have confirmed that [redacted].

205. *For Erste Abwicklungsanstalt*, applying the artificiality ribbon in its current form to its transactional data finds that [redacted].

206. *For Portigon AG*, applying the artificiality ribbon in its current form to its transactional data finds over two hundred transactions that [redacted].

**C. Application of the Artificiality Ribbon to the Wider Class**

207. I have also been asked to conduct a similar analysis in applying an artificiality ribbon to *Defendants'* data, to determine how absent Class Members fare under it.

208. I understand discovery is ongoing. I further understand that efforts to interpret, "clean," and analyze Defendants' data is ongoing. I thus am not in a position at this time to apply the artificiality ribbon to *all* of Defendants' data, but can supplement my opinions using the same methodology discussed herein when deemed appropriate to do so.

209. For the data produced by Nomura, BNPP, Morgan Stanley, HSBC, and Credit Suisse, I analyzed the transactional data for vanilla swaps and European swaptions. For the swaptions, I presumed they were all physically settled.[33] I analyzed transactions in the 2, 3, 4, 5, 7, 10, 15, 20, and 30 year tenors. Finally, I eliminated from the analysis transactions that could be identified as being done between two Defendants.

210. Of the 532 analyzed Nomura counterparties, applying the artificiality ribbon in its current form finds that [redacted] were negatively impacted on at

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33 This presumption is conservative because cash-settled swaptions have two opportunities to be negatively impacted, *i.e.*, they can experience both price and cashflow damages as explained above. Generally speaking, physically settled swaptions can only be negatively impacted when they are entered into.

least one transaction. These counterparties were responsible for [redacted] of the notional value of all the analyzed Nomura transactions.

211. Of the 1,732 analyzed BNPP counterparties, applying the artificiality ribbon in its current form finds that [redacted] were negatively impacted on at least one transaction. These counterparties were responsible for [redacted] percent of the notional value of all the analyzed BNPP transactions.

212. Of the 4,582 analyzed Morgan Stanley counterparties, applying the artificiality ribbon in its current form finds that [redacted] were negatively impacted on at least one transaction. These counterparties were responsible for [redacted] of the notional value of all the analyzed Morgan Stanley transactions.

213. Of the 620 analyzed HSBC counterparties, applying the artificiality ribbon in its current form finds that [redacted] were negatively impacted on at least one transaction. These counterparties were responsible for [redacted] of the notional value of all the analyzed HSBC transactions.

214. Of the 2,712 analyzed Credit Suisse counterparties, applying the artificiality ribbon in its current form finds that [redacted] were negatively impacted on at least one transaction. These counterparties were responsible for [redacted] percent of the notional value of all the analyzed Credit Suisse transactions.

215. I note that this analysis only looks at each bank's counterparty information in isolation. Thus, under the current methodology, a Class Member whose transaction *with Nomura* was not negatively impacted would not show up in the above statistics as an impacted Class Member, even if that same Class Member in reality *was* negatively impacted on transactions with other Defendants. To get a full

census of how many Class Members managed *always* to avoid being negatively impacted, the analysis would need to look at *all* the Defendants' transactional data in such a way that one track the same Class Member's transactions across multiple Defendant data productions. As discussed above, I understand efforts to do this are underway.

## IX. The Role of the Conspiracy to Rubber Stamp the Reference Rate in Enabling Bang-the-fix and Reporting Delay Manipulations

### A. Common Proof

216. Plaintiffs allege that Defendants conspired to fix prices by agreeing to submit quotations to the ISDAfix process that were identical to the Reference Rate disseminated by ICAP. Proving the existence of this conspiracy involves common evidence and common proof.

217. An observable implication of a conspiracy to submit quotations identical to the Reference Rate—to "rubber stamp" that rate—is that a very high rate of bank submissions match the Reference Rate. During the period 2006 through late 2012, this was indeed the case. This fact is documented thoroughly in the Report of Dr. Michael Williams.

### B. Unilateral Conduct

218. Absent a conspiracy among Defendants to rubber stamp the Reference Rate, individual banks would have had a far weaker incentive to engage in the manipulative conduct that Plaintiffs allege.

219. As noted at ¶¶61-63 *supra*, "banging the fix" was costly to any bank that engaged in this conduct. The manipulating bank incurred the cost of the temporary price

impact caused by its excessive purchases or sales. Moreover, manipulative trades exposed the manipulating bank to market risk until the position was unwound. The bank could profit from this conduct only if the impact on the final ISDAfix generated a profit that more than offset these costs, including the cost of bearing additional risk.

220. If other banks had submitted quotations to ICAP based on their independent competitive views of swap rates, these submissions would have tended to diverge from a market price that diverged from competitive values due to manipulative trading by any individual bank. This would have reduced, and potentially eliminated, the effect of manipulative trading on the final ISDAfix rate. This, in turn, would have reduced, and potentially eliminated, the financial benefit from manipulative trading.

221. Furthermore, Defendants would have had little unilateral incentive to rubber stamp the Reference Rate unless this facilitated manipulative trading.

222. Thus, manipulative trading and the conspiracy to rubber stamp the Reference Rate were highly complementary. Without a conspiracy to rubber stamp the Reference Rate, the unilateral incentive to engage in manipulative trading would have been far weaker, and arguably non-existent.

223. The above analyses seek to capture the movement associated with particular trades that were identified as manipulative. As discussed above, this is an inherently conservative methodology in that it begins with a requirement that a trader actually express, in a way captured by discovery in this case, statements of intent sufficient to distinguish trades done to "bang the fix," from those done for other purposes.

**C. Artificiality Caused by Rubber Stamping**

224. Rubber stamping not only affected the artificiality in ISDAfix rates by enhancing the effect of bang-the-fix manipulations, but even on days when bang-the-fix episodes did not occur (or where the documentary evidence that such an event occurred is lacking), rubber stamping could have impacted the ISDAfix rates, and hence damaged Plaintiffs. Further, given sufficient data, this impact can be calculated on a formulaic basis, and added to the artificiality ribbon described *supra*.

225. Specifically, participants in the ISDAfix process were supposed to provide ICAP with the swap spread at which they were willing to buy and sell benchmark swaps with a notional value of $50 million; submissions were to represent

> "a rate which is the mean of where that dealer would *itself* offer and bid a swap in the relevant maturity for a notional equivalent of $50 million of whatever amount is deemed market size in that currency for that tenor to an acknowledged dealer of good credit in the swap market. *That rate should not be where the dealer sees mid-market away from itself, but should be a function of its own bid/offer spread*." (Emphasis added.)

226. Note that this required participating banks to submit the midpoint of their *own* bid-offer.

227. ICAP was then to calculate the truncated mean of these submissions, and add this mean to the relevant Treasury yield (from BrokerTec) to determine the final ISDAfix. The truncated mean calculates an average of submissions excluding the four highest and four lowest rates: this is sometimes referred to as the "topping and tailing" process. Note that by rubber stamping, Defendants did not submit their own swap spread, but instead merely rubber stamped the Reference Rate provided by ICAP. Therefore, to the extent that the truncated average of Defendants' actual swap rates deviated from the rubber stamped Reference Rate, rubber stamping caused the ISDAfix

rates to deviate from those that would have obtained had Defendants followed the appropriate procedure. Such deviations could have harmed Plaintiffs.

228. Thus, a but-for rubber stamping ISDAfix rate can be calculated applying the ISDAfix procedure to measures of the Defendants' actual bid-ask midpoint swap rates in the 11:00AM-11:15AM period. Quantifying the deviations between the ISDAfix rates that would have obtained had Defendants not rubber stamped, and the ISDAfix rates that were produced in part as a result of rubber stamping, requires data on Defendants' own swap rates. Research is ongoing to determine if there are acceptably reliable alternative sources of pricing data in order to perform these calculations.

229. Potential sources of data on Defendant-specific swap rates include: (a) bank submissions to financial reporting services, such as Bloomberg or Tradeweb; (b) the bank's actual transactions on a given day; (c) rates used by the bank to "mark to market" their transactions for internal reporting purposes; and (d) market data regarding Treasuries yields. I understand efforts to gather these and other indicators of each bank's actual willingness to enter into a swap at a given rate are ongoing. If a sufficiently robust set of data were to be gathered, it would possible to create a "but for" ISDAfix submission for each bank on each day, with all of the panel banks' "but for" submissions being used to calculate, using the same "topping and tailing" methodology used by ICAP, the final "but for" ISDAfix rates. Given the requisite Defendant-specific data, this would be a purely arithmetic calculation that could be applied on a Class-wide basis.

230. The difference between this but-for rate and the actual but-for rate represents an additional source of artificiality that could be added to the artificiality ribbon described *supra*.

231. My research into the matters discussed in this report is ongoing, and I reserve the right to modify or supplement my opinions as additional information becomes available, including in response to the opinions of any experts retained by Defendants.

Dr. Craig Pirrong

Dr. Craig Pirrong

7/28/17

Date

**Appendix 1**

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Concentrations in finance, economics and econometrics.

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**EMPLOYMENT**

BAUER COLLEGE OF BUSINESS, UNIVERSITY OF HOUSTON, Houston, TX. Professor of Finance and Director, Global Energy Management Institute, 2003-present.

OKLAHOMA STATE UNIVERSITY, Stillwater, OK. Watson Family Professor of Commodity and Financial Risk Management and Director, Center for Risk Management, 2001-2003.

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LEXECON, INC., Chicago, Illinois. Economist (November 1987-December, 1988).

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Craig Pirrong. Regulate in Haste, Repent at Leisure: Private and Public Orderings in OTC Derivatives Markets. In E. Brousseau and J. M. Glachant (eds.), *Oxford Handbook on International Economic Governance*. Oxford, 2017 .

"Exchanges: The Ultimate Manufactured Markets." In E. Brousseau and J. M. Glachant (eds.), *The Manufacturing of Markets*, Cambridge, 2014.

"Structural Models of Commodity Price Dynamics." In H. Geman (ed.), *Encyclopedia of Quantitative Finance*; *Risk Management in Commodity Markets*, Wiley, 2008.

"Lattice Approaches to Pricing Derivatives." In R. Kolb and J. Overdahl (eds.), *Companion to Financial Derivatives*.

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"Pricing Power Derivatives: Theory and Matlab Implementation." In J. London, *Modeling Derivatives Applications in Matlab, C++, and Excel*. Financial Times Press, 2006.

"Market Microstructure Issues." In A. Kleit (ed.), *Electric Choices: Deregulation and the Future of Electric Power*. Rowan and Littlefield, 2006.

"The New Economy: Implications for the Organization and Structure of Securities Markets." In D. Jones (ed.), *The New Economy Handbook*. The Academic Press, 2003.

"Pricing Forwards and Options Using the Mesh-Based Partial Differential Equation Approach."

R. Jameson (ed.), *Energy Modelling and the Management of Uncertainty*. Risk Publications, 1999. (Republished in 2005).

"Pricing Energy Derivatives," with Kaushik Amin and Victor Ng. Chapter 4 in R. Jameson (ed.), *Managing Energy Price Risk*. Risk Magazine Publications, 1994. (Republished in 1999 and 2004).

"The Market for Treasury Securities: Microstructure and Market Power." Chapter 1 in P. Knapp (ed.), *The Treasury Securities Market*: *The Scholars' Assessment*. Homewood, IL: Business One Irwin, 1994.

"The Economics of Risk Based Capital Requirements." Chapter 33 in K. Lehn and R. Kamphuis (eds.), *Modernizing U.S. Securities Regulation*. Homewood, IL: Business One Irwin, 1993.

**Books**

*Commodity Price Dynamics: A Structural Approach*, Cambridge University Press, 2011.

*Corners and Squeezes: The Economics, Law, and Public Policy of Financial and Commodity Market Manipulation*. Kluwer Academic Publishers, 1996.

*Grain Futures Contracts: An Economic Appraisal*. With R. Kormendi and D. Haddock. New York: Kluwer Academic Publishers, 1993.

*The Origins and Resolution of the Thrift Crisis*. With V. Bernard, R. Kormendi and E. Snyder. New York: Kluwer Academic Publishers, 1989.

**Amicus briefs***

*NRG Power Mktg. v. Maine PUC*, 2008 U.S. Briefs 674 (U.S. July 14, 2009)*

*Morgan Stanley capital Grp v. Public Util. Dist. No. 1 of Snohomish County*, Washington 2006 U.S. Briefs 1457 (U.S. Nov. 28, 2007)*

**PAPERS PRESENTED**

"A Bill of Goods: Clearing and Systemic Risk." Oxford University Conference on Derivatives After the Crisis, 2013. Bank of England, Banque de France, and European Central Bank Conference on OTC Derivatives, 2013.

"The Industrial Organization of Execution, Clearing, and Settlement in Financial Markets." Haas/Sloan Conference on the Law & Economics of Organization, University of California, Berkeley, 2012.

"The Mutualization of Default Risk, Fungibility, and Moral Hazard: The Economics of Default Risk Sharing in Cleared and Bilateral Markets." ISNIE Annual Conference, Scotland, 2010. Notre Dame Financial Regulation Conference, 2010.

"Stochastic Volatility and Commodity Price Dynamics." Texas A&M University, 31 October, 2008. Institute of Financial Mathematics Conference, Champuloc, Italy, 21 January 2008.

"The Price of Power." Commodities 2007. University of London, 17 January, 2007.

"Modeling Issues in Commodity Markets." Commodities 2007. University of London, 18 January, 2007.

"Momentum In Futures Markets." 2005 European Finance Association Meetings, Moscow, Russia, 25 August, 2005. University of Illinois, September, 2006.

"Upstairs, Downstairs." 2003 European Finance Association Meetings, Glasgow, 27 August, 2003.

"Upstairs, Downstairs." 2003 Midwest Finance Association Meetings, St. Louis, March 2003.

"The Price of Power." 2002 European Finance Association Meetings, Berlin, 28 August, 2002.

"The Price of Power." 2002 Bachelier Finance Society Second World Congress, Crete, 12 June, 2002.

"Technological Change, For-Profit Exchanges, and the Self-Regulation of Financial Markets." American Law and Economics Association Meetings, New York, 7 May, 2000.

"Manipulation in Power Markets." University of California Energy Institute Restructuring Conference, Berkeley, 17 March, 2000.

"A Positive Theory of Financial Exchange Organization." International Society of the New Institutional Economics Meetings, Paris, 18 September, 1998.

"A Positive Theory of Financial Exchange Organization." American Law and Economics Association Meetings, Berkeley. 8 May, 1998.

"Efficient Deterrence of Manipulation in Futures Markets." American Law and Economics Association Meetings, Chicago. 6 May, 1996.

"Raising Revenue in the Worst Way: The Economic Effects of Asymmetric Hedge Taxation." Virginia Tech Symposium on "Hedge Taxation After *Arkansas Best*: Law, Economics, and Public Policy." 21 July, 1993.

"Fundamentals and Volatility: Storage, Spreads, and the Dynamics of Metals Prices." National Bureau of Economic Research Summer Institute Workshop on Asset Pricing. 20 July, 1993. American Finance Association Meetings, 3 January, 1993.

"Price Dynamics in Physical Commodity Spot and Futures Markets." Econometric Society Meetings, 7 January, 1993. Western Finance Association Meetings, June, 1993. ORSA/TIMS Meetings, November, 1993.

"Still Nature's Metropolis?" Kalo Hineman Symposium on Grain Futures Market Delivery Issues at the Commodity Futures Trading Commission, 15 September, 1991.

"Maintaining the Integrity of the Futures Delivery Process: The Economics of Manipulation and its Deterrence." American Bar Association/Virginia Tech Conference on Market Manipulation, 9 November, 1990.

"Multiple Delivery Points: Manipulation, Liquidity, and Basis Risk." American Bar Association/Virginia Tech Conference on Market Manipulation, 10 November, 1990.

Seminar presentations at North Carolina State University, Vanderbilt University, Southern Methodist University, the Federal Reserve Bank of Atlanta, the University of Missouri, the University of Kansas, Arizona State University, Babson University, Yale University Law School, the Michigan Business and Law Schools, the University of Chicago, the Tuck School of Business at Dartmouth University, North Carolina State University, the University of Alberta, Virginia Tech University, Washington University, Columbia University Law School, and the Commodity Futures Trading Commission.

## CURRENT RESEARCH ACTIVITY

### Papers Under Review

"Rocket Science, Default Risk, and the Organization of Derivatives Markets." First round, *Journal of Law and Economics*.

### Selected Working Papers

"The Mutualization of Default Risk, Fungibility, and Moral Hazard: The Economics of Default Risk Sharing in Cleared and Bilateral Markets."

"The Economics of Clearing in Derivatives Markets: Netting, Asymmetric Information, and the Sharing of Default Risk Through a Central Counterparty."

"The Industrial Organization of Trading, Clearing, and Settlement in Financial Markets."

"The Valuation of Power Options in a Pirrong-Jermakyan Model."

"Momentum in Futures Markets"

"Bund for Glory, or, It's a Long Way to Tip a Market."

"Upstairs, Downstairs: Electronic vs. Open Outcry Markets."

"The Macrostructure of Electronic Financial Markets."

"The Organization of Electronic Financial Markets."

"Third Markets and the Second Best."

"The Price of Power: Valuation of Power and Weather Derivatives."

"Manipulation of Power Markets."

"The Economic Implications of *Arkansas Best*: Asymmetric Tax Treatment of Hedge Income, Hedging Effectiveness, and Price Discovery."

"The Effects of *Arkansas Best* on Hedge Ratios."

"Brave New World? The Prospects for Computerized Futures Trading."

"A Structural Model of Cross Hedging Risk."

"Two Cheers for Follow-on Research in Pharmaceutical Markets."

"The Asset Management Incentives Implicit in FSLIC Assisted Acquisition Agreements."

"Futures Markets as Implicit Loan Markets: The Case of Grains."

**Research in Progress**

Momentum in Futures Markets.

Storable Commodity Price Dynamics and Commodity Derivatives Pricing.

Power Price Dynamics.

Pricing Contingent Claims on Power and Weather.

Clearing Mechanisms in Derivatives Markets: Efficiency and Distributive Issues.

Rights Aspects of Commodity Exchanges

**Reports**

"Not Too Big to Fail: Systemic Risk, Regulation, and the Economics of Trading Firms." Trafigura, 2015.

"The Economics of Commodity Trading Firms." Trafigura, 2014.

"Market oversight for cap and trade: efficiently regulating the carbon derivative market." Brookings Institute, 2009.

"An Evaluation of the Performance of Oil Price Benchmarks During the Financial Crisis." WTI Report U. of Houston, 2009.

"Woodpulp Futures: Establishing the Essential Facts." Report to OM Stockholm, 1996.

"Agricultural Futures Exchange in Germany for Europe: Feasibility-Design-Implementation." Report to the Warentermiborse, 1995.

"Strengthening the Winnipeg Commodity Exchange Canola Futures Franchise." Report to the Winnipeg Commodity Exchange, 1995.

"The Costs and Benefits of Adding Local Traders to the Deutsche Terminbörse." Report to the Deutsche Terminbörse, 1994.

"Derivatives Exchanges, Liquidity, and Locals: A Look to the Future." Catalyst Institute Report, 1994.

"Is There a Future for Stock Branch Indices?" Catalyst Institute Report, 1994.

"The Contribution of Dual Trading to the Liquidity of New York Mercantile Exchange Energy Contracts" (with NERA). Report for the New York Mercantile Exchange submitted to the Commodity Futures Trading Commission in support of NYMEX's application for a waiver from the dual trading ban contained in the 1992 CFTC re-authorization bill.

"Political Rhetoric and Stock Price Volatility: A Case Study." Catalyst Institute Report, 1993.

"The Relation Between Oil and Gasoline Futures and Spot Prices" (with Victor Ng). Report submitted to the New York Mercantile Exchange, 1992.

"An Economic Analysis of the Grain and Oilseed Delivery Mechanism at the Chicago Board of Trade." Report submitted to the Chicago Board of Trade, 1991.

"Crisis Resolution in the Thrift Industry: Beyond the December Deals" (with Victor Bernard, Roger Kormendi, and Ted Snyder). Reported submitted to the Federal Home Loan Bank Board, 1989.

**Refereeing Activities**

*American Economic Review*; *Economic Inquiry*; *International Journal of Law and Economics*; *Journal of Business*; *Journal of Economic Dynamics and Control; Journal of Economics and Finance*; *Journal of Finance*; *Journal of Financial Markets*; *Journal of Futures Markets*; *Journal of Industrial Organization*; *Journal of Law and Economics; Journal of Quantitative Financial Analysis; Journal of Risk; Review of Financial Studies; Journal of Economic Behavior and Organization; Journal of Business and Economic Statistics; Managerial and Decision Economics; Journal of Economics and*

*Business*.

**FELLOWSHIPS**

Oscar Mayer Fellow, University of Chicago (1983-1986)

**RESEARCH GRANTS**

Montreal Exchange grant to evaluate feasibility of introducing new commodity futures contracts. OM Stockholm and OMLX, London grant to study the feasibility of a pulp futures market and to design pulp futures and futures options contracts, 1996.

Winnepeg Commodity Exchange grant to study the contracts, rules, and bylaws of the WCE, with the objective of making recommendations to revise them in order to improve the performance of the Exchange's markets, 1994.

Catalyst Institute/DTB Deutsche Terminbörse grant to study the effects of attracting local traders to the DTB, 1994.

Catalyst Institute/DTB Deutsche Terminbörse grant to study the feasibility of new currency derivatives contracts, 1994.

Catalyst Institute/DTB Deutsche Terminbörse grant to study the feasibility of stock branch index derivatives, 1994.

Virginia Tech Center for Study of Futures and Options Markets grant to study the economic implications of the Internal Revenue Service policy on the taxation of hedging gains and losses 1993.

Warner Lambert Corporation grant for the study of competition in pharmaceutical markets 19901991.

Chicago Board of Trade grant to study grain futures market delivery issues 1990-1991.

**EXECUTIVE TEACHING**

Bayerische Vereinsbank, 1995

Anheuser-Busch, 1996.

Energy Power and Risk Management Courses and Conferences, March, June, September, and December, 1999, May 2000.

Peabody Coal Co., 2000.

HSM II Program, Olin School of Business, Washington University, Spring 2000.

**PERSONAL**

Married to Terry Lehman Pirrong. Two children: Renee Elise and Genevieve Corinne. Hobbies: history (especially U.S. Civil War), agonizing over Chicago sports teams, and exercise.

**DR. CRAIG PIRRONG**
**EXPERT TESTIMONY and RETENTIONS**
**2005-2013**

Puget Sound Energy, Inc. v. All Jurisdictional Sellers of Energy, et al FERC Docket No. EL01-10-085.

San Diego Gas & Electric Company v. Sellers of Energy and Ancillary Services Into Markets Operated by the California Independent System Operator Corporation And the California Power Exchange. FERC Docket No. EL00-95-248.

In re Amaranth Natural Gas Commodity Litigation, S.D.N.Y. 07-C-6377.

Randy Schaefer et. al. vs. Bayer AG et. al., 2010 (Written report). Circuit Court of Lonoke County, AR CV2006-413.

In re Natural Gas Commodity Litigation, S.D. NY 03-CV-6186(VM).

In re BP Propane Indirect Purchaser Antitrust Litigation, N.D. IL Eastern Division 06-C-3541.

Lenny Joe Kyle et. al. vs. Bayer AG et. al. Circuit Court of Woodruff County, AR. CV-2008-107.

Energy Trading Partners L.P. et al v. Federal Energy Regulatory Commission. Docket Number IN06-3-003.

RCG v. Trading Technologies, International, Inc., N.D. IL Eastern Division 95-C-4088.

Asarco LLC v. American Mining Corp. Bankruptcy Court Southern District of Texas, 05-21270.

Energy Trading Partners L.P. et al v. Federal Energy Regulatory Commission. Docket Number IN06-3-003.

Trading Technologies International, Inc. v. eSpeed, Inc., N.D. IL Eastern Division 04-C-5312.

Trading Technologies International, Inc. v. GL Trade, N.D. IL Eastern Division 05-C-4120.

Trading Technologies International, Inc. v. Future Path Trading LLC., N.D. IL Eastern Division 05-C-5164.

Trading Technologies International, Inc. v. CQGT, LLC and CQG, Inc., N.D IL Eastern Division 05-CV-4811.

Power Authority of the State of New York v. Entergy Nuclear Indian Point 3, LLC and Entergy Nuclear Fitzpatrick, LLC, 7:00-cv-06346-CM

Josef A Kohen, Breakwater Trading LLC, and Richard Hershey v. Pacific Investment Management Co. et al. N.D. IL 05-C-4681.

In re Williams Securities Litigation, 2006. N.D. OK 02-CV-72-SPF-FHM.

AEP Energy Services v. Bank of Montreal, 2005. S.D. OH Eastern Division C2-03-335.

In re: Dairy Farmers of America, Inc. Cheese Antitrust Litigation, N.D. IL 09-cv-03690.

In re: Optiver Commodities Litigation, S.D.N.Y. 08-cv-6842.

In re: Platinum and Palladium Commodities Litigation, S.D.N.Y. 10-cv-3617.

Lehman Brothers International (Europe) v. AG Financial Products, Inc. CPLR Sections 501, 503, 509 and GOL-1402 (Supreme Court of the State of New York, County of New York).

PJM Up To Congestion Transactions FERC Docket Number IN10-5-000.

Fifth Market Inc. v. CME Group Inc. et al. D. Del. 08-cv-520.

Chicago Mercantile Exchange, Inc. v. $5^{th}$ Market Inc., CBM2013-00027 (PTAB 2013) .

**DR. CRAIG PIRRONG**
**EXPERT TESTIMONY**
**2011-2016**

Public Utilities Commission of the State of California v. Sellers of Long-Term Contracts to the California Department of Water Resources, and California Electric Oversight Board v. Sellers of Energy and Capacity under Long-Term Contract with the California Department of Water Resources, FERC Docket Nos. EL02-60-007 and EL02-62-006 (Consolidated).

Lehman Brothers International v. AG Financial Products Inc. index number 653284/2011 Supreme Court of the State of New York, County of New York.

Trading Technologies International, Inc. v. CQGT, LLC and CQG, Inc., N.D IL Eastern Division 05-CV-4811.

Fifth Market Inc. v. CME Group Inc. et al. D. Del. 08-cv-520.

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Puget Sound Energy, Inc. v. All Jurisdictional Sellers of Energy, et al FERC Docket No. EL01-10-085.

San Diego Gas & Electric Company v. Sellers of Energy and Ancillary Services Into Markets Operated by the California Independent System Operator Corporation And the California Power Exchange. FERC Docket No. EL00-95-248.

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**Appendix 2**

## Materials Relied Upon

### Academic Papers

A. Kraus and Hans Stoll, Price Impacts of Block Trading on the New York Stock Exchange, 27 J. of Finance (1972)

Albert S. Kyle, Continuous Auctions and Insider Trading, 53 Econometrica (1985)

Alex Boulatov and Thomas George, Hidden and Displayed Liquidity in Securities Markets With Informed Liquidity Providers, 26 Rev. of Fin. Studies (2013)

Ananth Madhavan and Minder Cheng, In Search of Liquidity: Block Trades in the Upstairs and Downstairs Markets, 10 Rev. of Financial Studies (1997)

Ananth Madhavan, Matthew Richardson, and Mark Roomans, Why Do Security Prices Change? A Transaction-Level Analysis of NYSE Stocks. 10 Rev. of Financial Studies (1997)

Black, F., "The pricing of commodity contracts", *Journal of Financial Economics* (1976)

Bruce Mizrach, The Next Tick on Nasdaq, 8 Quant. Fin. (2008)

Bruno Biais, Larry Glosten, and Chester Spatt, Market Microstructure: A Survey of Microfoundations, Empirical Results, and Policy Implications, 8 J. Financial Markets (2005)

Carole Comerton-Forde and Talis J. Putnins, Measuring Closing Price Manipulation, 20 J. of Financial Intermediation (2011)

Craig Pirrong, The Economics of Commodity Market Manipulation, 5 J. of Commodity Markets (2017)

Hans Stoll, Friction, 55 J. of Finance (2000)

Hendrik Bessembinder and Herb Kaufman, A Cross-Exchange Comparison of Execution Costs and Information Flow for NYSE-listed Stocks, 46 J. of Financial Econ. (1997)

Hendrik Bessembinder, Issues in Assessing Execution Costs, 6 J. of Financial Markets (2003)

Joel Hasbrouck, Empirical Market Microstructure: The Institutions, Economics, and Econometrics of Securities Trading (2007)

Joel Hasbrouck, Measuring the Information Content of Stock Trades, 46 J. of Finance (1991)

Joel Hasbrouck, Trades, Quotes, Inventories, and Information, 22 J. of Financial Econ. (1988)

Kerry Back, Insider Trading in Continuous Time, 5 Rev. of Fin. Stud. (1992)

Lawrence Glosten and Lawrence Harris, Estimating the Components of the Bid-Ask Spread, 14 J. of Financial Economics (1985)

Lawrence Glosten and Paul Milgrom, Bid, Ask and Transaction Prices In a Specialist Market With Heterogeneously Informed Traders, 14 J. of Financial Econ. (1985)

Michael Brandt and Kenneth Kavajecz, Price Discovery in the U.S. Treasury Market: The Impact of Order Flow and Liquidity on the Yield Curve, 59 J. of Finance (2004)

Michael Fleming, Measuring Treasury Market Liquidity, 9 Federal Reserve Bank of New York Policy Rev. (2003)

Onem Ozocak, Price Impact of Informed Trades in the U.S. Treasury Markets, 3 J. of Econ. and Financial Studies (2015)

Paul Milgrom and Nancy Stokey, Information, Trade and Common Knowledge, 26 J. Econ. Theory (1982)

Praveen Kumar and Duane Seppi, Futures Manipulation With Cash Settlement, 47 J. of Fin. (1992)

Praveen Kumar and Duane Seppi, Limit Order and Market Orders With Optimizing Traders, Carnegie-Mellon Working Paper (1993)

Roger Huang and Hans Stoll, Dealer Versus Auction Markets: A Paired Comparison of Execution Costs on NASDAQ and NYSE, 41 J. of Financial Econ. (1996)

Roger Huang and Hans Stoll, The Components of the Bid-Ask Spread: A General Approach, 10 Rev. of Financial Studies (1997)

Ron Kaniel and Hong Liu, So What Do Informed Traders Use, 79 J. of Bus. (2006)

Sugato Chakravarty and Craig Holden, An Integrated Model of Market and Limit Orders, 4 J. of Fin. Intermediation (1995)

Thierry Foucault, Sophie Moinas, and Eric Theissen, Does Anonymity Matter in Electronic Limit Order Markets, 20 Rev. of Fin. Studies (2007)

**Analyst Reports**

Michael Fleming, Bruce Mizrach, and Giang Nguyen, The Microstructure of a U.S. Treasury ECN: The BrokerTec Platform, FRBNY Staff Reports No. 381 (2017)

**Books**

Brigo, D. & Mercurio, F. (2006). *Interest Rate Models -Theory and Practice*. Springer Finance. Berlin: Springer-Verlag Berlin Heidelberg

Foucault, T., Pagano, M., & Röell, A. (2013). *Market Liquidity: Theory, Evidence, and Policy*. Oxford University Press

Lyons, R. K., (2006). *The Microstructure Approach to Exchange Rates*. MIT Press

O'hara, M. (1995). *Market Microstructure Theory*. Vol. 108. Cambridge, MA: Blackwell

**Bate-Stamped Documents**

ISDAFIX-0030203

***BNP Paribas***

BNPP_AK_00279885
BNPP_AK_00279887
BNPP_AK_00279888
BNPP_AK_00279889

***Credit Suisse***

CS-ISDA-LIT 00462379
CS-ISDA-LIT_00462380

***HSBC***

HSBC-ISDAFIXLIT-00662367
HSBC-ISDAFIXLIT-00662827

***ICAP***

ICM-001491281-2399
ICM-001510006-34
ICM-000214845-9362
ICM-000219364

***Morgan Stanley***

MS-ALASKA00065481
MS_ALASKA00353872
MS_ALASKA00353873
MS_ALASKA00353874

***Nomura***

AK-NSI-00695615

***Alaska Electrical Pension Fund***

ISDA_Alaska_000000848
ISDA_Alaska_000000992

***City of New Britain, Connecticut***

ISDA-NEWB0000050-53
ISDA-NEWB0000073-79

***County of Montgomery, Pennsylvania***

ISDA_MONTC0_00000021-28

***County of Washington, Pennsylvania***

ISDA-WASH0000030-59
ISDA-WASH0000186-96
ISDA-WASH0000480-87
ISDA-WASH00001172-3

***Erst Abwicklungsanstal***

AK-WF00013015
AK-WF-00001532
AK-WF-00000702-03
ISDA_Portigon_EAA_0000003741-46
ISDA_Portigon_EAA_0000003752-56
ISDA_Portigon_EAA_0000003757-60
ISDA_Portigon_EAA_0000003761-65
ISDA_Portigon_EAA_0000003774-77
ISDA_Portigon_EAA_0000003819-22
ISDA_Portigon_EAA_0000003849-53
ISDA_Portigon_EAA_0001983981-84

***Genesee County Employees' Retirement System***

ISDA_GENESEE_00001498-822

***Pennsylvania Turnpike Commission***

ISDA_PATPK_0000111-18

***Portigon AG (f/k/a WestLB AG)***

AK-WF00001798
AK-WF00013008
ISDA_Portigon_EAA_0000003623-26
ISDA_Portigon_EAA_0000003766-69
ISDA_Portigon_EAA_0000003778-81
ISDA_Portigon_EAA_0000003782-85
ISDA_Portigon_EAA_0000003786-89
ISDA_Portigon_EAA_0000003794-97
ISDA_Portigon_EAA_0000003798-801
ISDA_Portigon_EAA_0000003815-18
ISDA_Portigon_EAA_0000003832-35
ISDA_Portigon_EAA_0000003836-39
WestLB/Portigon/EAA 001 - 256312L_256313L
WestLB/Portigon/EAA 001 - 3468306NY
WestLB/Portigon/EAA 001 - image006
WestLB/Portigon/EAA 001 - image007
WestLB/Portigon/EAA 001 - image010
WestLB/Portigon/EAA 001 - image011
WestLB/Portigon/EAA 001 - image014
WestLB/Portigon/EAA 001 - image015
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WestLB/Portigon/EAA 001 - image020
WestLB/Portigon/EAA 001 - image021
WestLB/Portigon/EAA 001 - image024
WestLB/Portigon/EAA 001 - image025
WestLB/Portigon/EAA 001 - image026
WestLB/Portigon/EAA 001 - image033

**CFTC Orders**

Order, In the Matter of The Goldman Sachs Group, Inc. and Goldman, Sachs & Co,, CFTC Dkt. 17-03

**Court Documents**

Final Consent Order of Permanent Injunction, Civil Monetary Penalty and Other Relief as to Defendants Optiver US et al, SDNY 08 Civ. 6560, 2012

**Data From Vendors**

Published ISDAfix Rates and Treasury Coupons from Bloomberg, L.P.

Eurodollar and Treasury Futures from Chicago Mercantile Exchange (CME)

**Expert Reports**

Expert Report of Michael A. Williams, Ph.D. (July 28, 2017)
Expert Report of Robert Farrell (July 28, 2017)